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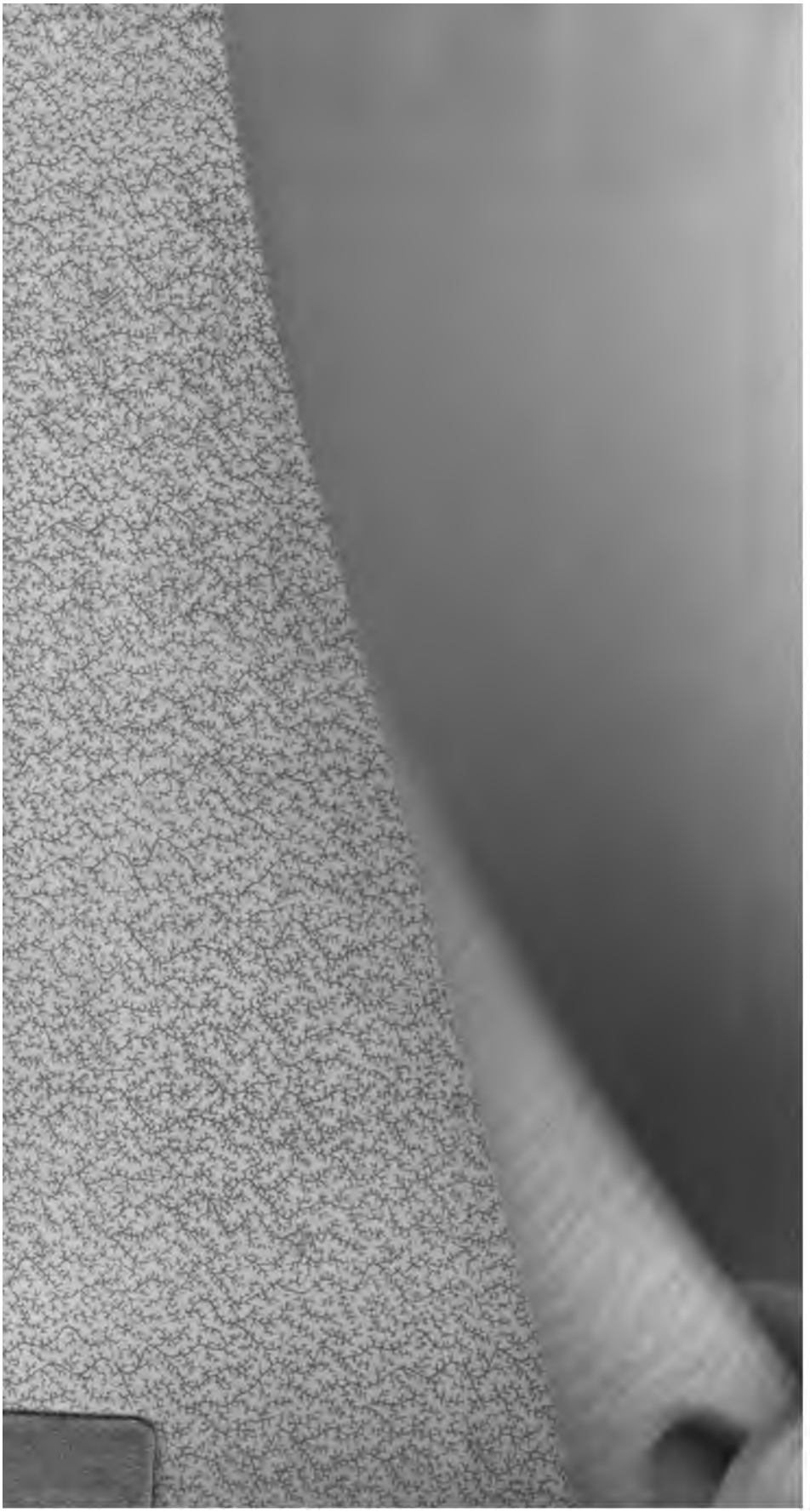

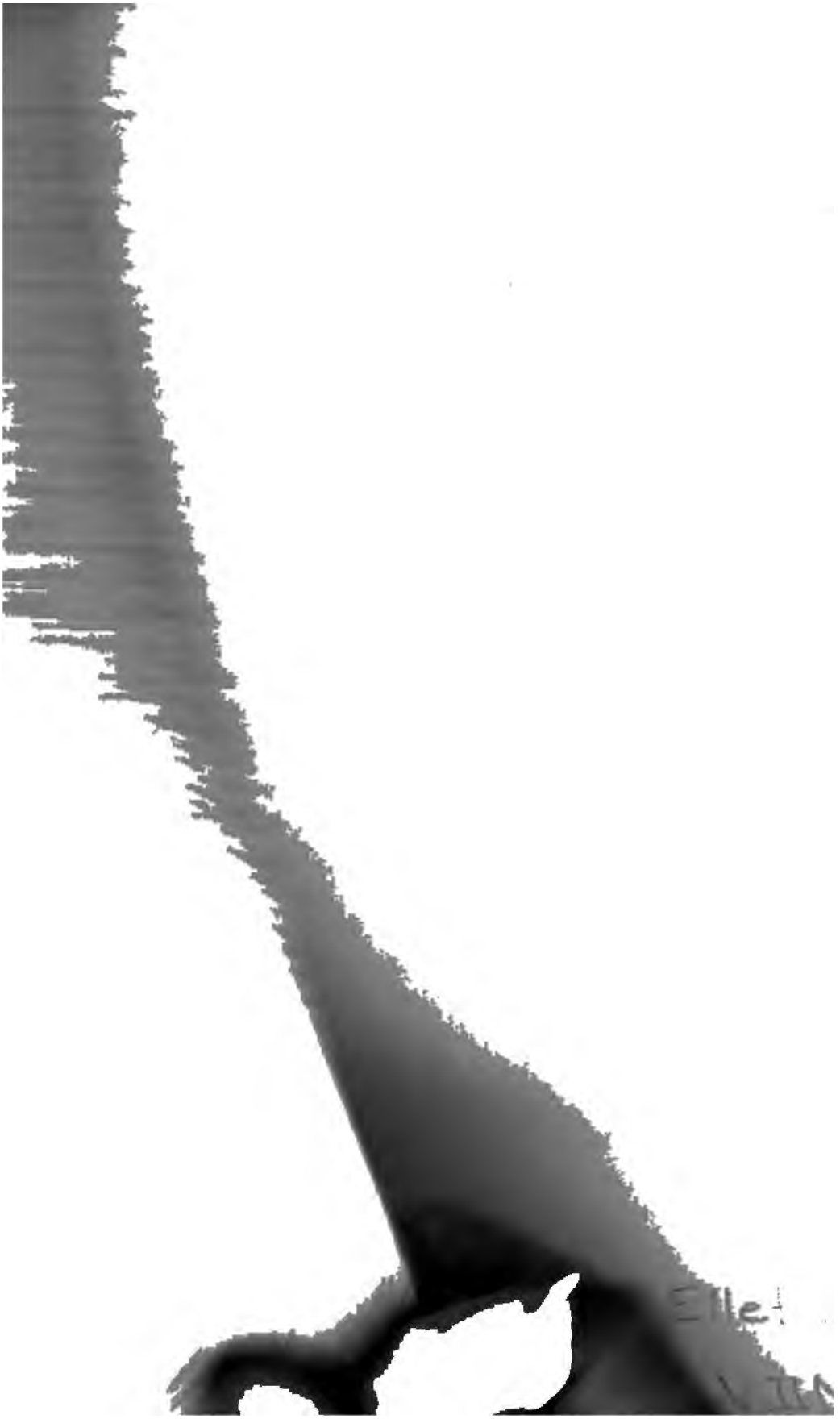

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INUNDATIONS

OF THE

DELTA OF THE MISSISSIPPI.

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THE

MISSISSIPPI AND OHIO RIVERS:

CONTAINING PLANS FOR THE PROTECTION

OF THE

DELTA FROM INUNDATION;

AND

INVESTIGATIONS OF THE PRACTICABILITY AND COST

OF

IMPROVING THE NAVIGATION

OF THE

OHIO AND OTHER RIVERS BY MEANS OF RESERVOIRS

WITH

An Appendix,

ON

THE BARS AT THE MOUTHS OF THE MISSISSIPPI.

BY

CHARLES ELLET, JR.,

CIVIL ENGINEER.

PHILADELPHIA:

LIPPINCOTT, GRAMBO, AND CO.

1853.

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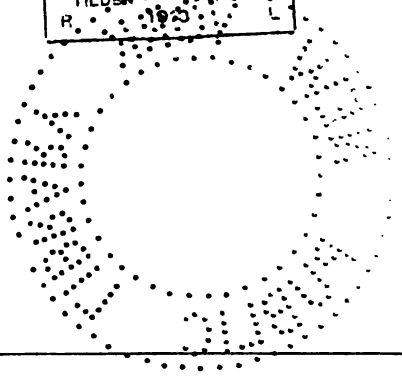

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PUBLISHERS' PREFACE.

THE following pages, containing the views of Mr. ELLET on the overflows of the Delta of the Mississippi, and suggestions for their prevention, were originally presented in a Report to the War Department, and published in the Executive Documents of the Senate.

This Report was made under the authority of an act of Congress, directing the Secretary of War to institute such surveys and investigations as were necessary to the preparation of adequate plans for protecting the Delta from inundations, and increasing the depth of water on the bars at the mouths of the Mississippi.

The author of this Report, though not an officer of the Government, or in the employ of the Department, was called to this important duty, and authorized to make such investigations as would enable him to devise

and report suitable plans for accomplishing the purposes of the Congressional act.

The results of the investigations, as presented to the Department, and printed by the Senate, are republished in this volume in a style more creditable to the author, and more worthy of the importance of the vast interests affected, than the original edition.

Containing the views of a practical engineer on the grandest and most difficult branch of his profession, with which the skill and science of men have yet attempted to cope; and foreshadowing a new and extensive department of Civil Engineering, it has been thought by the publishers, that, apart from all the local and great pecuniary interest which the subject involves, along the Mississippi, this work could not fail to command the attention and excite the interest of many professional and scientific readers.

But this Memoir on the Mississippi is intimately connected, in many respects, with the original views communicated to the public by the same writer, through the Transactions of the Smithsonian Institution, on the improvement of the Ohio. The bold and magnificent plan—in which Mr. Ellet proposed to maintain the

navigation of this great river through the droughts of summer, by supplying water to its channel from artificial lakes and reservoirs to be constructed on its tributary streams—though at first generally viewed as wild and chimerical, has gradually won its way into the public confidence, until it is now advocated by many of the most prominent practical engineers of the country.

This work, also, may be regarded as the foundation of a new branch of engineering, which, in the progress of the country in wealth and population, is destined to acquire increasing interest from year to year.

The Memoir on the Ohio must be regarded as the complement of that on the Mississippi. The views in each are supported by careful, extensive, and systematic observations and measurements. Taken together, these essays present a grand scheme of public improvement, by which at the same time, and by the same expedient, the navigation of the great rivers of the West may be improved, and their borders relieved and ultimately protected entirely from inundations.

In the Appendix, is a part of the Report by the same author on the Improvement of the Navigation across

the Bars at the Mouths of the Mississippi; in which a new, and, it is believed, the true theory of the formation of those bars is presented, and simple means proposed for their reduction.

The proofs of the present edition of these works have been carefully revised and corrected by the author.

PHILADELPHIA,
January 25, 1853.

INTRODUCTION.

In this paper, the causes of the more frequent and more extensive overflows of the Delta of the Mississippi, in recent than in former times, are considered, and plans suggested for the mitigation of the evil.

The greater frequency and more alarming character of the floods are attributed—

Primarily, To the extension of cultivation throughout the Mississippi Valley, by which the evaporation is thought to be, in the aggregate, diminished, the drainage obviously increased, and the floods hurried forward more rapidly into the country below.

Secondly, To the extension of the levées along the borders of the Mississippi, and of its tributaries and outlets, by means of which the water that was formerly allowed to spread over many thousand square miles of low lands, is becoming more and more confined to the immediate channel of the river, and is, therefore, compelled to rise higher and flow faster, until, under the increased power of the current, it may have time to excavate a wider and deeper trench to give vent to the increased volume which it conveys.

Thirdly, To *cut-offs*, natural and artificial, by which the distance traversed by the stream is shortened, its slope and velocity increased, and the water consequently brought down more rapidly from the country above, and precipitated more rapidly upon the country below.

Fourthly, To the gradual progress of the delta into the sea, by which the course of the river, at its embouchure, is lengthened, the slope and velocity there are diminished, and the water consequently thrown back upon the lands above.

It is shown that each of these causes is likely to be progressive, and that the future floods throughout the length and breadth of the delta, and along the great streams tributary to the Mississippi, are destined to rise higher and higher, as society spreads over the upper States, as population adjacent to the river increases, and the inundated low lands appreciate in value.

For the prevention of the increasing dangers growing out of these several co-operative causes, six distinct plans are discussed and advocated:—

First. Better, higher, and stronger levées in lower Louisiana, and more efficient surveillance—a local measure, but one requiring State legislation, and official execution and discipline.

Second. The prevention of additional cut-offs; a restraint which may call for national legislation, or possibly judicial interference, to prohibit the States and individuals above from deluging the country below.

Third. The formation of an outlet of the greatest attainable capacity, from the Mississippi to the head of

Lake Borgne, with a view, if possible, to convert it ultimately into the main channel of the river.

Fourth. The enlargement of the Bayou Plaquemine, for the purpose of giving prompt relief to that part of the coast which now suffers most from the floods, viz.: to the borders of the Mississippi from above Baton Rouge to New Orleans.

Fifth. The enlargement of the channel of the Atchafalaya, for the purpose of extending relief higher up the coast, and conveying to the sea, by an independent passage, the discharge from Red River and the Washita.

Sixth. The creation of great artificial RESERVOIRS, and the increase of the capacity of the lakes on the distant tributaries, by placing dams across their outlets, with apertures sufficient for their uniform discharge—so as to retain a portion of the water above until the floods have subsided below. It is proposed by this process to compensate, in some degree, for the loss of those natural reservoirs which have been and are yet to be destroyed by the levées; and, at the same time, and by the same expedient, improve the navigation of all the great tributaries of the Mississippi, while affording relief to the suffering and injured population of the delta.

It will be seen that these several plans harmonize with each other, and may be carried on simultaneously.

It will be shown, moreover, that they will all be needed, and that they must be adopted promptly and prosecuted vigorously, to afford efficient and timely protection; and that, if adopted, and pressed forward boldly, they will ultimately secure the immediate object of Con-

gress—the protection of the coasts of the Mississippi from overflow, and, simultaneously, the perfection of twenty thousand miles of precarious navigation, and the ultimate drainage and cultivation of fifteen or twenty millions of acres of uninhabitable swamps.

Nothing will more forcibly impress the mind of the practical man with the inestimable value of the Mississippi and its tributaries—as a social, commercial, and political bond of this happy country, than the comprehensive study of the grand and beautiful problem of controlling their waters.

The writer is fully aware of the distrust with which some of his views on this subject have been, and may yet be for a season, regarded. But he submits his plans to the calm consideration of an enlightened public, in the confident belief that every year, and each succeeding flood, will secure for them closer attention and additional strength.

INUNDATIONS

OF THE

DELTA OF THE MISSISSIPPI.

PART I.

OF THE PHYSICAL CHARACTERISTICS OF THE DELTA OF THE MISSISSIPPI.

THE Delta of the Mississippi is usually assumed to extend from the Gulf of Mexico to the point at which rock *in situ* is first encountered on both sides of its channel, and supposed to be found in the bed. This point is near the village of Commerce, about twenty-eight miles above the mouth of the Ohio. But if we mean to designate by THE DELTA that formation of alluvial soil through which the Mississippi now flows, and which has been raised above the sea by the earthy matter brought by the river from the highlands, it will be difficult to assign its true northern limit. There is no evidence that the Gulf of Mexico, in the present order of things, and under the present adjustment of land and water, ever washed the base of the hills north of the Ohio.

If that fact be assumed, it involves the further assumption that there existed at some remote period a

cataract or rapids, having a descent greater than the pitch of Niagara, somewhere above the mouth of the Ohio. The elevation of the low-water surface of the Mississippi, between Commerce and Cape Girardeau, is 285 feet above the level of the ocean; and if the present level of the sea ever extended up to that point, the Mississippi must then and there have precipitated its waters over a ledge two hundred and eighty-five feet high. Without intending to maintain this assumption, which has never been supported by facts or demonstration, for the present purposes we may adopt the mouth of the Ohio as the head of the delta, though only for the convenience of assigning some limit to the field of the proposed investigation.

To be able to form a just conception of the present physical constitution of the delta, and the causes of its overflow, we must imagine a great plane sloping uniformly from the mouth of the Ohio, in a direction deviating but little from a due southerly course, to the Gulf of Mexico. The length of this plane, from the mouth of the river to the waters of the gulf, is 500 miles. Its northern extremity is elevated 275 feet above the surface of the sea, and is there and everywhere nearly level with low water in the Mississippi River. Its total descent, following the highest surface of the soil, is about 320 feet, or at the rate of 8 inches per mile.

The breadth of this plane, near the mouth of the Ohio, in an east and west direction, is from thirty to forty miles; and at the Gulf of Mexico it spreads out to a width of about one hundred and fifty miles. It is in-

closed on the east and west by a line of bluffs of irregular height and extremely irregular direction.

This plane, containing about 40,000 square miles, has been formed in the course of ages from the material brought down from the uplands by the Mississippi and its tributaries. The river has therefore raised from the sea the soil which constitutes its own bed. It flows down this plane of its own creation, in a serpentine course, frequently crowding on the hills to the left, and once passing to the opposite side and washing the base of the bluff which makes its appearance on the west at the town of Helena.

The actual distance from the mouth of the Ohio to the coast of the gulf is, as stated, in round numbers, 500 miles. The computed length of the Mississippi River, from its confluence with the Ohio to the mouth of the Southwest Pass, is 1,178 miles; and the average descent at high water $\frac{27}{100}$ of a foot, or 3¼ inches per mile.

The course of the river is therefore lengthened out nearly seven hundred miles, or is more than doubled by the remarkable flexures of its channel; and the rate of its descent is reduced by these flexures to less than one-half the inclination of the plane down which it flows.

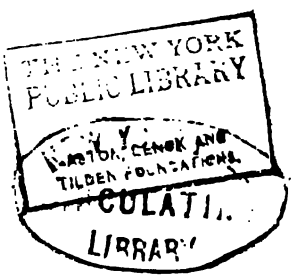
In the summer and autumn, when the river is low and water is scantily supplied by its tributaries, the surface of the Mississippi is depressed at the head of the delta about forty feet, and as we approach New Orleans, twenty feet below the top of its banks. It then flows along sluggishly, in a trench about 3,000 feet wide, 75 feet deep at the head, and 120 feet at the foot, and in-

closed by alluvial and often caving banks, which rise, as stated, from 20 to 40 feet above the water.

But when the autumnal rains set in, the river usually rises until the month of May, when it fills up its channel, overflows its banks, and spreads many miles over the low lands to the right and left of its trace. This leads to another important feature in the characteristics of this great stream.

The Mississippi bears along at all times, but especially in the periods of flood, a vast amount of earthy matter suspended in its waters, which the current is able to carry forward so long as the river is confined to its channel. But when the water overflows the banks, its velocity is checked, and it immediately deposits the heaviest particles which it transports, and leaves them upon its borders; and as the water continues to spread further from the banks, it continues to let down more and more of this suspended material—the heaviest particles being deposited on the banks, and the finest clay conveyed to positions most remote from the banks. The consequence is, that the borders of the river, which received the first and heaviest deposits, are raised higher above the general level of the plane than the soil which is more remote; and that, while the plane of the delta dips towards the sea at the rate of eight inches per mile, the soil adjacent to the banks slopes off at right angles to the course of the river, into the interior, for five or six miles, at the rate of three or four feet per mile.

These lateral slopes, with the high-water and low-water levels of the Mississippi and the artificial levées,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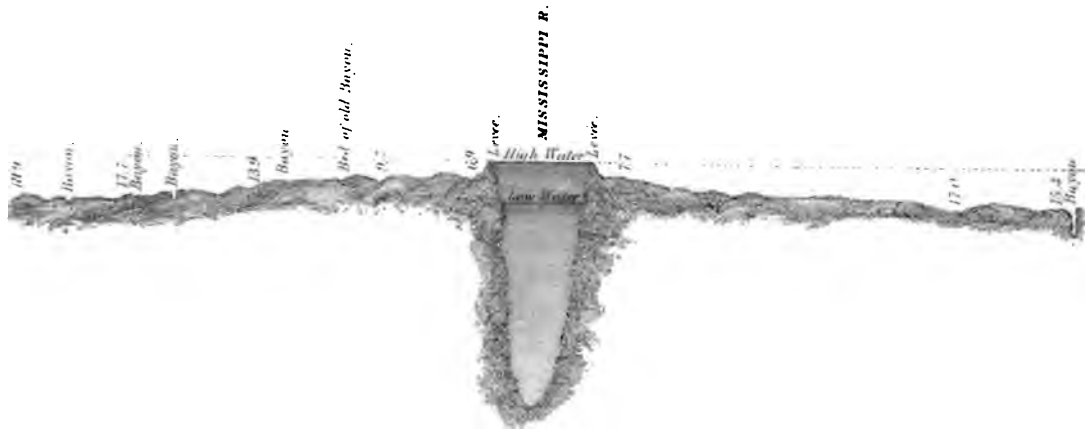

Hor. Scale 5000 Feet to the Inch — Ver. Scale 100 Feet to the Inch

are exhibited in the annexed section (Plate I.), which is a fair average obtained from a number of surveys made at various points between Donaldsonville and Baton Rouge, by Messrs. H. and William G. Waller, civil engineers.

It will be perceived from this section and description, that, in times of flood, the surface of the Mississippi is 18 or 20 feet higher than the level of a great part of the actual delta; and that, at low water, its surface is found in the very lowest depression of the delta; so that all the lateral streams and adjacent low grounds have then a natural drainage towards its channel.

The lands immediately on the borders of the river are extremely fertile, and often highly cultivated. But as they are all subject to inundation during the high floods of the river, they are guarded by artificial embankments, which have been thrown up in front of each plantation by the individual proprietors. The water presses upon these embankments, and often produces breaches through them; when, as may be readily appreciated from the representation above, it rushes in a deep column into the low grounds, from which it had been previously excluded by the levées, and sweeps over any improvements that may have obtained a foothold there. It is to find means of obviating the disasters incident to these crevasses, and to prevent the overflow of these low grounds, or swamp lands generally—covering, it is supposed, nearly 40,000 square miles—that the investigation, of which the results are now given, has been instituted.

What is here said of the Mississippi applies equally,

though with modifications due to the difference in the magnitude of the streams, to all the tributaries, great and small, which flow into it, from the mouth of the Ohio to the sea. Each tributary is inclosed, at low water, by banks twenty or thirty feet high, which it overflows at periods of flood, mingling its waters of overflow in the lateral low grounds with those of the Mississippi. The immediate borders of each tributary likewise exhibit deposits made by the tributary, highest at the edge of the channel, and sloping off laterally to the adjacent lowlands; presenting a narrow strip of cultivated or arable soil near the winding channel, and great unbroken swamps beyond.

The delta of the Mississippi was, therefore, in its natural condition, at high water, a vast inundated tract, through the lowest depression of which might be traced the channel of the river, absorbing numerous tributaries in its course, each of which found its way to the common recipient along the most depressed portions of the adjacent lowlands.

In times of great and general flood, there was then but an inconsiderable area of land elevated above the water; but, as the river fell, the course of its channel might be defined by two narrow strips of soil, rising in parallel belts above the surface; from which, as the water continued to recede, there would become gradually visible the parallel borders of the tributaries, and their countless bayous, forming a double network of natural embankments, with rivers of various dimensions inclosed between them, over the whole area of the delta.

It is in the highest degree important that this description should be made clear; for it will presently be shown that it is essentially the exclusion of this water of overflow from the swamps, that is now creating so much distress in lower Louisiana; while to remove the water and reclaim these swamps, has become a prominent object of National and State legislation.

The subject is of vast interest, highly complicated, and full of difficulty. But the lands which are now annually overflowed, may certainly be estimated at fully 16,000,000 of acres, which, if relieved by any effectual process, would be worth, at the government price, $20,000,000; but converted, as they may be, into sugar and cotton fields, would possess a value that it might seem extravagant to state; while the annual loss and distress of the present population, caused by the inundations of the river, can scarcely find a parallel in many localities, excepting in the effects of national hostilities.

WIDTH OF THE MISSISSIPPI.

The Mississippi is usually described as remarkable for the uniformity of its surface-width. And if we take great sections, and compare the average breadth in consecutive reaches extending from one great tributary to another, we shall certainly be struck with the uniformity of these averages, and the very small impression produced upon the apparent magnitude of the stream by the immense volumes of water poured into it by its greatest arms. This fact has, indeed, an important

bearing upon the subject of overflows; for we shall find that, notwithstanding the vast contributions received from the Ohio, the Arkansas, White, St. Francis, Red, and other rivers, the Mississippi, in flood, actually conveys less water into the Gulf of Mexico in a unit of time, *through its channel*, than it carries past Cape Girardeau, or other points, twelve hundred miles above its mouth.

But, notwithstanding this general truth, this great river presents as frequent and as sudden changes of width, depth, and velocity as are exhibited by other streams. Let us take, for example, three measurements of the width of the entire river between banks, in the neighborhood of St. Louis.

WIDTH OF THE MISSISSIPPI AT ST. LOUIS.

	FEET.
Width opposite Market Street, taken at low water in 1839, by Charles Ellet, Jr.	3,444
Width above Bloody Island, taken in 1837, by Captain R. E. Lee	4,314
Width at the Narrows, three miles above St. Louis, taken in 1837, by Captain R. E. Lee	1,835

These measurements show variations in the width at the surface, of nearly one hundred and forty per cent. in the space of three miles; yet the average width at or near St. Louis does not differ materially from the average at Vicksburg or at Donaldsonville. In fact, it will be seen, in comparing the following widths of surface, measured at various points, from Cape Girardeau to the mouth of the river, that there is no general increase of the breadth of the Mississippi, in passing from what is supposed to be its ancient channel to that alluvial bed which it has raised for itself from the sea.

TABLE I.

OF THE WIDTH OF THE MISSISSIPPI BETWEEN BANKS.

POINTS OF OBSERVATION.	FEET.
Cape Girardeau, about one and a half mile above	2,500
Above mouth of Ohio, about two miles	1,530
Below mouth of Ohio, about one mile	4,031
Below Memphis, half a mile	2,830
At the Horse-Shoe cut-off	2,940
Above mouth of Arkansas River, three-quarters of a mile	2,810
Below mouth of Arkansas River, three-quarters of a mile	3,730
At American Bend, upper side, below Columbia	3,365
At American Bend, lower side	3,285
Terrapin Neck, Fig. 3, letter P	3,440
Terrapin Neck, lower side, at letter P′	3,540
Above Vicksburg, about seven miles	3,513
Above Vicksburg Landing, half a mile	2,243
Below Vicksburg, about three miles	4,400
Above Palmyra Island bend	4,048
Below Palmyra Island bend	5,613
Above Grand Gulf, about four miles	3,644
Below Grand Gulf, about three miles	5,900
Above the mouth of Red River, about half a mile	2,545
Below the mouth of Red River, about one mile	3,655
In Raccourci cut-off (river still becoming wider here)	1,761
At Tunica Bend	3,323
Baton Rouge (from the Report of Senate committee of Louisiana)	2,500
Above Plaquemine, one and a half mile	2,170
Below Plaquemine, one and a half mile	2,790
Above Donaldsonville, about one mile	2,483
Below Donaldsonville, about half a mile	3,553
Bonnet Carré bend, above the crevasse	2,925
Bonnet Carré bend, below the crevasse	2,983
Sauvé's plantation, above the crevasse	2,375
At McMaster's plantation, about eleven miles below New Orleans	2,425
Average width of the Mississippi	3,236

From these measurements—for which the points of observation were not particularly selected, but taken with a view to obtain other information incident to this investigation—the width of the Mississippi may be said to vary, in the course of the river through the delta, from 2,200 feet to 5,000 feet, though there are occasionally encountered places where these limits are materially exceeded. In the succeeding investigations, when it may become necessary to use a mean expression for the value of the width, 3,300 feet will be assumed for that general average.

There is one fact having a most important practical bearing, which it will be expedient to notice here, as resulting from these measurements. The width of the Mississippi, in the Raccourci cut-off, is, at this time, but 1,761 feet, or only half the measured width at points a few miles above and below the cut-off. This passage has now been open more than three years, yet the power of the whole river rushing through it has not been found sufficient to cut out that narrow neck much beyond the half of the average width of the stream. As the pass becomes enlarged from year to year, the force of the river through it will be correspondingly diminished, and centuries may therefore roll by, before that part of the Mississippi is opened as wide as the average dimensions of the channel.

This fact will be again adverted to when we come to consider the merits of that theory which treats with indifference the constantly increasing volume poured down by the river; confiding in the hope that the abra-

sive power of the current will increase as the volume of water discharged increases, and that this increasing power will always secure an adequate passage for the surplus water. The writer may, therefore, assert now, as he will be forced to maintain hereafter, that this is a delusive hope, and most dangerous to indulge, because it encourage a false security.

OF THE DEPTH OF THE MISSISSIPPI.

The depth of the Mississippi, from above the entrance of the Missouri to a point below the mouth of the Arkansas, exhibits a decided increase with each additional tributary that is received. But below the Arkansas, and especially below the mouth of the Yazoo, though the extreme depths, in mid-channel, may vary materially—sometimes diminishing down to less than ninety feet, and sometimes rising to more than one hundred and eighty feet—they exhibit no general or progressive increase.

The following table shows the maximum depths found at high water in sounding across from shore to shore at the several points for which the foregoing widths are given:—

TABLE II.

OF THE EXTREME DEPTHS OF THE MISSISSIPPI AT HIGH WATER OF 1850.

POINTS OF OBSERVATION.	FEET.
Cape Girardeau, about one and a half mile above	66.5
Cape Girardeau (to high water of 1844)	76.5
Above mouth of Ohio, about two miles	77.5
Below mouth of Ohio, about one mile	71.3
Below Memphis, half a mile	102.5
At the Horse-Shoe cut-off	72.8
Above mouth of Arkansas River, three-fourths of a mile	81.5
Below mouth of Arkansas River, three-fourths of a mile	81.0
At American Bend, upper side	103.6
At American Bend, lower side	79.1
Terrapin Neck, Fig. 3, letter P	87.6
Terrapin Neck, lower side, at letter P	102.1
Above Vicksburg, about seven miles	120.0
Above Vicksburg Landing, half a mile	120.5
Below Vicksburg, about three miles	84.0
Above Palmyra Island bend	96.3
Below Palmyra Island bend	91.3
Above Grand Gulf, about four miles	105.5
Below Grand Gulf, about three miles	76.5
Above the mouth of Red River, about half a mile	118.0
Below the mouth of Red River, about one mile	128.0
In Raccourci cut-off	107.0
At Tunica Bend	87.7
Above Plaquemine, one and a half mile	123.5
Below Plaquemine, one and a half mile	128.0
Above Donaldsonville, about one mile	117.5
Below Donaldsonville, about half a mile	103.2
Bonnet Carré bend, above the crevasse	107.9
Bonnet Carré bend, below the crevasse	76.4
Sauvé's plantation, above the crevasse	135.3
At McMaster's plantation, about eleven miles below New Orleans	100.0

From Vicksburg down to New Orleans, we may fairly assume the average depth, in mid-channel way, at high

water, to be one hundred and fifteen feet, though there are many points where the depth exceeds one hundred and eighty feet, and others where the extreme does not exceed seventy feet. It is liable also to frequent variations in the same points; light deposits being left on the bottom when the river is low, and swept out again when its force is increased by the flood. The greatest depth found in the course of this investigation, was under the bluffs at Grand Gulf, where the lead once reached two hundred feet. A depth of one hundred and eighty-four feet was obtained above Donaldsonville, and one hundred and eighty feet in several other places.

It is worthy of note that the maximum depth of the section taken in the Raccourci cut-off, as well as the width of surface, after that pass had been three years exposed to the action of the river—here greatly increased in power by the contraction of the water-way—is still decidedly below the average.

The areas of the high-water sections of the Mississippi, at prominent points, from Cape Girardeau, above the mouth of the Ohio, to the English Turn, below New Orleans, are shown in the following table:—

TABLE III.

OF THE SECTION OF THE MISSISSIPPI BETWEEN BANKS, IN THE HIGH WATER OF 1850.

POINTS OF OBSERVATION.	SQ. FEET.
At Cape Girardeau, about one and a half mile above	105,544
At Cape Girardeau, about one and a half mile above (flood of 1844)	130,624
Below mouth of the Ohio, about one mile	235,333
Below Memphis, half a mile	143,212
At the Horse-Shoe cut-off	161,221
Above mouth of the Arkansas River, three-fourths of a mile	171,190
Below mouth of the Arkansas River, three-fourths of a mile	196,390
At American Bend, upper side	170,160
At American Bend, lower side	187,170
Terrapin Neck, upper side	178,220
Terrapin Neck, lower side	168,130
Above Vicksburg, about seven miles	160,164
Above Vicksburg Landing, half a mile	177,200
Below Vicksburg, about three miles	207,800
Above Palmyra Island bend	187,220
Below Palmyra Island bend	256,292
Above Grand Gulf, about four miles	175,773
Below Grand Gulf, about three miles	264,797
Above the mouth of Red River, about half a mile	194,530
Below the mouth of Red River, about one mile	268,646
In Raccourci cut-off	148,790
At Tunica Bend	233,892
Baton Rouge (from the report of engineers of Senate committee)	212,500
Above Plaquemine, one and a half mile	181,500
Below Plaquemine, one and a half mile	199,280
Above Donaldsonville, about one mile	200,250
Below Donaldsonville, about half a mile	214,580
Bonnet Carré bend, above the crevasse (high water of 1849)	198,734
Bonnet Carré bend, below the crevasse (high water of 1849)	152,443
Sauvé's plantation, above the crevasse (high water of 1849)	182,031
At McMaster's plantation, about eleven miles below New Orleans	166,172
The average area of the high-water section of the Mississippi, from Vicksburg to Donaldsonville, inclusive, is	215,200
The average of the whole, from the mouth of the Ohio to New Orleans, is	200,000

It will be again observed, on inspecting this table, that the area of the section of the Mississippi in high water, through the Raccourci cut-off, is but little more than two-thirds of the average area from Vicksburg to Bonnet Carré. The average velocity of the current through that contracted pass, is, therefore, at least forty per cent. greater than the average velocity in other parts of the river below the mouth of the Arkansas. Yet, notwithstanding the fact that the water is so crowded in this gorge, and that its velocity is so much accelerated by the contraction of the channel, it makes exceedingly slow progress in opening the way and restoring the average normal dimensions of its section.

The conclusions which will be drawn from this fact will be found of the highest importance in treating of the effect of cultivation, of cut-offs, and the extension of the levées—indeed, in all measures tending to throw more water into any part of the channel in a given time. It will be seen that we must seek to determine the effect of every such increase of supply, without venturing to make allowances for any hypothetical augmentation of the water-way to be ultimately gained by the increase of the abrasive power of the current.

OF THE VELOCITY OF THE MISSISSIPPI.

Numerous observations were made in the course of this investigation, for the purpose of determining the velocity of the Mississippi. The result of these measurements shows an average surface-velocity in the

centre of the river, at high water, of about seven feet per second, or nearly five miles per hour; and occasionally places where the speed at the surface is ten or eleven feet per second, or fully seven miles per hour.

But, for computing the discharge of the river, it is necessary to be able to deduce approximately the velocity of all the currents beneath the surface, or the mean velocity, from observations made at the surface. This problem has occupied the attention of several eminent writers, among whom stand conspicuously the names of Du Buat and De Prony. The formulas published by these savants, respectively, have received the sanction of practical men, and are now almost universally adopted. Yet the experiments made during this inquiry have exhibited results which do not sustain the received rules, when applied to deep and rapid rivers, and which, in fact, are in some respects at variance with all the popular theories.

A primary object of the writer was to ascertain what deduction ought to be made from the observed velocities at the surface of the Mississippi, in order to represent fairly the mean velocity of the whole mass of the river.

For this purpose, lines of different lengths were procured, and so loaded that the lower end would sink, while the upper end, and the load at the lower, would be supported by a float on the surface. A line thus prepared was thrown into the river where the depth had been previously ascertained, and, when straightened out by the weight below, a surface-float was placed along-side of the one which supported the line, and

allowed to start from a drifting boat, with the same velocity. These floats were kept together until they were carefully timed as they passed a range previously established on the shores. They were then successively timed again as they passed a second parallel range, established five hundred feet lower down the river. It results from numerous trials made in this manner, in different parts of the river, in depths varying from fifty-four feet to one hundred feet, and in currents varying from three miles to seven miles per hour, that *the speed of the float supporting a line fifty feet long is almost always greater than that of the surface-float.* The average increase of velocity over the surface-velocity, with a line of fifty feet, obtained from nineteen observations, is *two per cent.*

Four observations in nineteen trials with the fifty-feet line, exhibited under-velocities less than the surface-velocities. With a line twenty-five feet long, the results were nearly the same in five observations; four of the results with the line being greater than the speed of the surface-float. A line seventy-five feet long in ninety-three feet water, showed a velocity a little over two per cent. greater than that of the surface-float.

A line seventy-five feet long, where the depth was eighty-two feet, showed a velocity of 2.6 per cent. *less* than that obtained at the surface. But experiments made on the speed so near the bottom must always be received with distrust, as the lower end of the line is liable to come in contact with the soil, or other fixed obstructions. (See note A.)

So far as these experiments go, they lead to the conclusion that the mean velocity of the Mississippi, instead of being less, is in fact about two per cent. greater than the mean surface-velocity. But it has not been deemed proper to make any additions to the volumes deduced from observations on the speed at the surface, in computing the total discharge of the river. It is the opinion of the writer, founded on these experiments and legitimate deductions from them, that the velocity of the water near the surface is retarded by its contact with the atmosphere. As we descend below the surface the effect of this retardation disappears; and at some point about midway between the surface and the bottom the velocity should be a maximum. But at the bottom, a further retardation of course has place, which the time of the writer, and the means at his disposal, did not permit him to study. Yet as such a retardation must occur, it has been deemed proper to assume that it will diminish, if it do not altogether neutralize, the increase of two per cent. observed in the velocities, with a fifty-feet line, over those obtained at the surface.

It is probable that the mean velocity of the Mississippi is a very small fraction greater than the mean velocity of its surface; but as the excess must be very small, certainly less than two per cent., it has been thought proper to compute the discharge in all cases from the surface-velocity only.

In deducing the average increase of velocity beneath the surface, no account has been taken of those observations which show remarkable under-currents produced

by eddies and local irregularities. On one occasion, in testing the velocity a few hundred feet from the shore, where the soundings showed a depth of thirty-nine feet, the velocity of a twenty-five feet line was found to be 20½ per cent. greater than that of the surface-float; and the speed of a buoy bearing a thirty-five feet line—sweeping within four or five feet of the bottom—was 17 per cent. greater than that of the surface.

These under-currents are very frequent below the salient angles of the shores, where eddies occur, and great disturbance of the water is produced. But the foregoing results were obtained from observations made in straight channels, where no such disturbing causes were observable.

A study of these observations will enable us, moreover, to account for an anomaly sometimes noticed in testing the surface-velocities at different distances from the shore in the same part of the river. It occasionally happens that the speed at the surface diminishes as the depth of the sounding increases; contrary to the received hypothesis, which assumes that, *cæteris paribus*, the velocity of the surface-current increases in some proportion with the depth of the channel. Still, these anomalous results are, in this case, only in appearance in conflict with the popular law. The depth of the river is due, not to the surface-velocity, but to the velocity of the water which is in contact with the bottom, and which produces the depth. The deeper soundings, found where the surface-velocities are diminished, are

clearly the result of under-currents of greater force than those at the surface.

It is proper to remark that it was only in the Mississippi, and its deep tributaries and outlets, that the under-velocities were found to exceed those obtained from the surface-floats. On repeating the same experiments in shallow mountain streams, of quick descent, the law commonly recognized was found to prevail, and the surface-floats passed always ahead of those which were attached to lines suspended at any depth beneath the surface.

OF THE VOLUME OF WATER DISCHARGED BY THE MISSISSIPPI.

It was an object of solicitude, on the part of the writer, to ascertain from actual measurement the volume of water discharged by the Mississippi at the top of the flood of April, 1851. But, at the moment when the river was thought to have reached its highest mark, the weather proved to be unfavorable for such experiments, which can only be correctly made at times of perfect calm. The least motion of the wind affects the velocity of the float and vitiates the result. Before suitable weather again occurred the water had receded below New Orleans, where the measurement was made, about six inches.

In that condition of the river, when the surface had fallen six inches, the volume discharged at a point eleven miles below the city, and below all the crevasses

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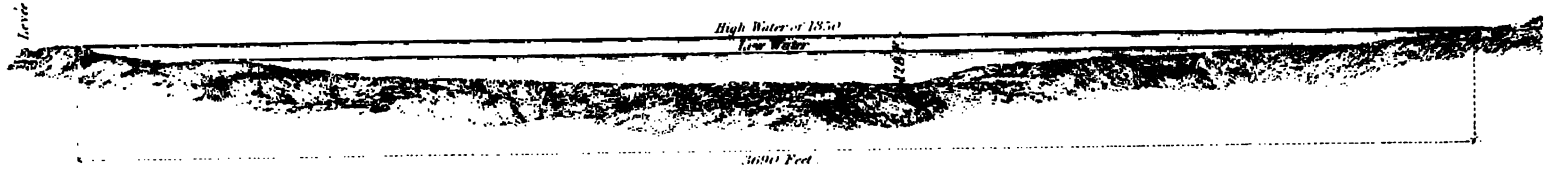
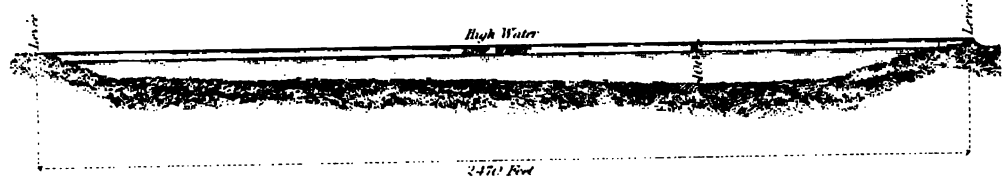
SECTION OF THE MISSISSIPPI RIVER 1 MILE BELOW RED RIVER.



Scale 500 Feet to the Inch.

SECTION OF THE MISSISSIPPI RIVER 11 MILES BELOW NEW ORLEANS.



Scale 500 Feet to the Inch

then running, was found to be 979,240 cubic feet per second. This measurement was made the 16th April, 1851.

Ten days after this gauging was completed, the weather proved again to be perfectly calm, and the opportunity was seized to ascertain the discharge a short distance below the mouth of Red River. The water had then receded at that place $2\frac{3}{10}$ feet from the highest mark attained there during the flood. The result, in this condition of the surface, exhibited a total discharge immediately below Red River, of 1,054,000 cubic feet per second.

We have, then, the following important results derived from these experiments:—

The discharge below Red River was . .	1,054,000 c. ft. per sec.
The discharge below New Orleans . .	979,240 " "
Lost between Red River and New Orleans .	74,760 cubic feet.

Even in this state of things, after the surface of the Mississippi had fallen $2\frac{3}{10}$ feet at the mouth of Red River, and only half a foot at New Orleans, the discharge below Red River exceeded the discharge at New Orleans, by 74,760 cubic feet per second.*

This fact will hereafter be found worthy of special note, when we come to discuss the practicability of defending the country below Red River, as has often been proposed, by simply strengthening the levées. When

* Sections of the Mississippi, at the points where these observations were made, are shown in Plate II.

the river had fallen $2\frac{3}{10}$ feet, the breaches in the guard-banks of the coast were still venting more water than would have sufficed, as we shall find, to raise the surface twelve inches when the flood was at its extreme height.

But before attempting to discuss this question, it is important to ascertain what volume of water escaped through all the crevasses below Red River at the top of the flood of 1851; and also, approximately, some method to determine the volume of water that will be needed to raise the surface of the river, when in flood, any given height. These questions involve the unknown relations of depths, slope, and velocity of rivers; questions which have been discussed by several able and distinguished writers, but which, nevertheless, must receive a further examination here.

But it will be useful first to record the actual discharge of the Mississippi in the extreme high water of 1851.

Below the mouth of the Red River, when the surface had receded $2\frac{3}{10}$ feet from its highest mark, the discharge per second was found, by measurements made April 26, 1851, to be, as already stated, .	1,054,000 cub. ft. per sec.	
To this add, for the diminution of the discharge due to the reduction of the surface $2\frac{3}{10}$ feet, by a formula to be hereafter presented	80,500	
And we obtain for the discharge of the Mississippi, in the high water of 1851, . .		1,134,500 c. ft.

This sum, however, expresses only the discharge through the channel. To obtain the total discharge we must include the volume vented by the Atchafalaya.*

The discharge of the Atchafalaya, below the mouth of the Bayou de Glaise, April 26, 1851, was	122,700 cub. ft. per sec.	
Add, for the diminution of the discharge due to the reduction of the surface there, $2\frac{13}{100}$ feet, at that date . . .	12,800	
Total discharge, per second, of the Atchafalaya, during the high water of 1851 . . .		135,500 c. ft.
Add discharge of the Mississippi, as above . . .		1,134,500
Aggregate discharge per second of the Mississippi and Atchafalaya together, at high water of 1851		1,270,000 c. ft.
But the flood of 1851 was three inches lower than that of 1850, immediately below the mouth of Red River. We cannot, therefore, estimate the high-water discharge of the Mississippi and Atchafalaya together, at the top of the flood of 1850, at less than, per sec. . . .	1,280,000 cub. ft.	

These results apply to observations made on the Mississippi above the Raccourci cut-off, and on the Atchafalaya just below the mouth of Bayou de Glaise.

There is a fact elicited by these investigations, and others conducted at higher points on the river, of great importance in this inquiry, and which has apparently heretofore escaped observation. It is the curious cir-

* The reader will find a description of the Bayou Atchafalaya in the following pages.

cumstance that the actual channel of the Mississippi—or what may be designated as the *Mississippi between banks*—carries more water, in times of flood, towards the head of the delta, than near the mouth of Red River, or thence to the sea. In other words, more water is discharged by the actual channel of the river immediately below the mouth of the Ohio, or even above the mouth, as high up as Cape Girardeau, than passes by Natchez or New Orleans, or any intermediate point.

The discharge of the Mississippi per second below New Orleans, at the top of the flood of 1851 (from measurements taken June 16, and corrected for extreme high water) was	995,000 c. ft.
The discharge through the channel below the mouth of the Red River when the surface was highest, June, 1851, was	1,134,500 c. ft.
The discharge of the channel at Memphis, at the top of the flood of May, 1850, as deduced from the report of Mr. Robert A. Marr, United States Navy, (see note B.) was	958,500 c. ft.
The discharge, one mile below the mouth of the Ohio, June 10, 1851, while the water was yet seven feet ten inches below the high water of 1850, and *nine feet* below that of 1849, and rising about one foot per diem, was	1,223,000 c. ft.
The discharge about one mile above Cape Girardeau, June 17, 1851, when the water was $4\frac{7}{10}$ feet below the high water of 1844, was . . .	1,025,000 c. ft.
The discharge at this point, above the mouth of the Ohio, during the high water of 1844, must have been, at least, per second	1,200,000 c. ft.

These quantities, it will be observed, are in all cases the volumes which flowed down between the banks of the river, and are exclusive of the waters of overflow which enter the swamps above, and feed and maintain the floods below.

If we compare the volume discharged in 1851 below the mouth of the Ohio, while the flood was yet nearly eight feet below the high water of 1850, with that known to have passed Memphis at the top of the flood of 1850, we shall have data fully to justify the conclusion that more than forty per centum of the volume discharged by the channel immediately below the mouth of the Ohio, passes over into the swamps of the southern counties of Missouri, and the northern counties of Arkansas, and escapes the measurements at Memphis. And, in order to form a correct judgment of the masses of water to be dealt with, in the attempt to control the floods of this river, it must be further observed that a great volume also leaves the channel of the Mississippi *above the Ohio*, and passes round through the swamps of Missouri, and consequently escapes even from the measurements below Cairo.

No effort has yet been made to ascertain by direct measurement the volume of water which, in times of flood, finds its way through the swamps on either side of the river; though this is, indeed, a very important element in the present inquiry. It was too late in the season for the writer to undertake that work, after he had ascertained its true bearing upon the subject on which it was his duty to report. To do it properly,

preparatory surveys should be made across the swamps before the flood comes down, so that the wave might be traced and the volume of overflow determined, from point to point, as it advances.

The quantities which are here stated, differ widely from the current estimates of the high-water burden of the Mississippi. But as they result from careful soundings, and simultaneous observations upon the velocity at each point where the depth was taken, so made as to divide the section of the river into numerous portions of which the area and velocity were known, they cannot possibly deviate materially from the precise truth.

LAWS OF DRAINAGE.

Several foreign writers on hydraulics have published formulæ derived from experiments, to exhibit the relations between the depths, slopes, and velocities of running streams. But their various equations are almost all derived from each other, or built upon the same observations; while these observations, limited in number, have been made on streams of very small dimensions. Where they are applied to great rivers, like the Mississippi or Ohio, they fail to give results in close agreement with the recognized facts. It has, therefore, been deemed advisable, indeed necessary, to deduce new and better formulæ from a wider range of experiments—embracing great rivers of gentle slope in full flood, and passing from those to smaller streams of abrupt descent, and in various conditions of their channels. But serious difficulties

were encountered in the attempt to frame such a formula from observations on the flow of the Mississippi. The movements of this great river are remarkable, and need to be carefully studied before the resulting law can be confidently applied. The river descends on an average slope of about three and a quarter inches per mile, and the mean velocity of its current is, of course, due to that slope. Yet it not unfrequently happens, that while the mass of the water which its channel bears is sweeping *to the south*, at a speed of four or five miles per hour, the water next the shore is running *to the north*, at a speed of one or two miles per hour.

It is no unusual thing to find a swift current and a corresponding fall on one shore towards the south, and, on the opposite shore, a visible current and an appreciable slope towards the north. In other words, the water is often running rapidly *up stream* on one side of the river, while sweeping with equal or much greater rapidity down stream, on the opposite side.

It is obvious, therefore, that no single or merely local observation on the rate of descent of the stream can be depended on for the determination of that element of an equation. The apparent slope is at every point affected by the bends of the river, and the centrifugal force acquired by the water in sweeping round the curves, and by the eddies which form on the opposite side, under the salient angles.

The surface of the river is not, therefore, *a plane*, but a peculiarly complicated warped surface, varying from point to point, and inclining alternately from side to side.

To neutralize, in some degree, the effect of such variations on the littoral measurements of the slope, levels and soundings were taken at different points along the shore, not very remote from each other, and mean slopes, depths, and velocities, derived from many observations. As a check to the results, and a guard against material error, the average slope, depth, and velocity were obtained for considerable distances, embracing many bends of the river. And, as a further check, the slopes, depths, areas, and velocities of the tributaries and outlets of the Mississippi, and of various small mountain streams, were collected and compared. A formula was then sought which should express the maxima, or central velocities, at the surface, in terms of the slope and maxima depths of each of these various streams.

The equation produced by these investigations is here submitted, with the experiments from which it was derived, and its application to each set of observations.

Let d represent the maximum depth of the river, in feet, at the place of observation; f, the slope of the surface, in feet, per mile; v, the velocity of the central surface-current, in feet, per second; then the formula proposed is

$$v = \frac{8}{10} d^{\frac{1}{2}} f^{\frac{1}{2}} + \frac{df}{20}.$$

The application of this formula to many of the facts obtained, with the amount of discrepancy in each case, will be found in note C.

It was further ascertained, from numerous observations conducted with much care, that the *mean velocity*

of a great river, in a straight channel, is about eighty per cent. of its maximum velocity, as has been obtained by De Prony and others for smaller streams.* This proportion is near enough for any practical application needed in this paper; it is, probably, as close a general approximation as can be made in the premises.

There is no necessity of any formula to determine the actual discharge of the Mississippi for any given height of flood or position; that has been done, as far as is requisite for any practical purpose, by direct measurement. But it will be convenient to have some means of determining, approximately, what will be the increased height of a flood, due to any given increase in the volume discharged, when the general dimensions and slope of the river are given.

The formula above will be applicable to this object, and will be frequently referred to in the course of this memoir. That formula expresses the value, in feet per second, of the central surface-velocity. Eight-tenths of that value is the approximate mean velocity of the whole section; which, being multiplied into the area of the section, in feet, will show the approximate discharge, in cubic feet.

It will be expedient here to make two applications of this formula, assuming for the constants dimensions corresponding with the general features of the Mississippi from Donaldsonville to Red River. We shall find, by

* The precise figures given by De Prony are, $v' = .8164580$; but the writer pretends to no such precision.

referring to the two preceding tables, that the average mid-channel depth, or the value of d, may be fairly assumed at one hundred and fifteen feet; the general width of surface at about 3,300 feet; the general slope, at high water, at $\frac{2.5}{1000}$ of a foot per mile; and the average area of water-way at 215,000 square feet.

By substituting these quantities in the formula, we shall have, for the usual mid-channel velocity at high water,

$$v = \frac{5}{6}(115 \times \tfrac{2.5}{1000})^{\frac{1}{2}} + \frac{115 \times .25}{20} = 5.73 \text{ feet per second.}$$

The mean velocity should be eight-tenths of this sum, or

$$v = 4.584 \text{ feet per second.}$$

The discharge per second will then become

$$D = 215{,}000 \times 4.584 = 985{,}560 \text{ cubic feet per second.}$$

But, if the surface should now rise 12 inches higher, in consequence of an increased supply of water, the value of d will become 116 feet; the slope, or value of f, will be about $\frac{2.54}{1000}$ feet, and the area of the average section will be increased to 218,300 square feet.

By substituting these quantities in the formula, we obtain for the new velocity, in mid-channel way,

$$v = \frac{5}{6}(116 \times .254)^{\frac{1}{2}} + \frac{116 \times .254}{20} = 5.8156 \text{ feet per second.}$$

The mean velocity is, therefore, in this case,

$$v = 4.6525 \text{ feet per second.}$$

The area of the channel, when the depth is increased

one foot by the elevation of the surface, is also increased, and becomes, as above assumed,

$$A = 215{,}000 + 3{,}300 = 218{,}300 \text{ square feet.}$$

The discharge per second will be, in this case,

$$D = 218{,}300 \times 4.6525 = 1{,}015{,}640 \text{ cubic feet per second.}$$

Comparing these results, we perceive that when the river is at its usual high-water stage, under the circumstances assumed for the example, the discharge per second is	985,560 cub. ft.
And when raised 12 inches higher, by any accidental increase of supply, the discharge must be . .	1,015,640 "
From which we deduce for the average volume which must be supplied to the channel when in full flood, in order to raise the surface one foot, from Red River to Plaquemine, per second .	30,080 cub. ft.

In applying this formula, however, it is proper to observe that there are two considerations which operate to augment the volume that would be required to produce this increased elevation. When the river is at or near its highest mark, it overflows long strips of level ground between the natural bank and the levée, where there is a sensible though inconsiderable motion. This increased area will, of course, assist in venting a part of the increased supply.

Again, when the river is rising, the slope of the surface at the point where the rise is progressing, is materially greater than the slope of the surface when at its highest limit, and still greater than the slope which has place there after the water has begun to recede. The effect of this consideration upon the velocity and dis-

charge of a river, in cases of rapid rise, is frequently very great. It often happens, at the beginning of a flood in the upper part of the Mississippi, that the water rises at the rate of three or even four feet in twenty-four hours. The average velocity before the rise may be assumed at two and a half miles an hour. The water, therefore, travels at the rate of sixty miles a day. Consequently, when the first signs of the flood are visible at a point sixty miles below the mouth of the Ohio, it may have risen three or four feet at the mouth; and the average slope must have experienced an increase, in that space of sixty miles, of $\frac{4}{5}$ of a foot per mile—which is about one-fifth of the slope of the river before the flood commenced. It is true that, in the lower part of the river, and when the wave has nearly reached its highest mark, the water rises much more slowly, and the increase of velocity attributable to this cause, is far less serious than in this example. But even in this case the effect will be perceptible; and it will not, therefore, be prudent, in the judgment of the writer, to estimate the increased volume which will be needed to raise the surface one foot in extreme high water, at a less average than 35,000 cubic feet per second.

This is submitted as a mean result, applicable only to the general or average dimensions of the lower Mississippi. No rule can be given which will apply to every position; for the width, depth, and area of the stream are most variable; and, as the same volume of water must pass through different sections, its velocity, both surface and mean, must be subject to continual change.

OF THE CREVASSES.

From the description which has been given of the delta, it will be easy for those not familiar with the formation of the valley of the Mississippi, to appreciate the danger to which the population there is continually exposed, in times of flood, from the inundations of the river, consequent on the giving way of the protecting levées. The condition of things in high water is faithfully represented in the diagram, Plate I. The surface of the river is there shown to be from five to seven feet above the surface of the cultivated fields on its borders; and the water is prevented from sweeping over these fields by artificial embankments, which now extend, in almost continuous lines, on both sides of the river, from below New Orleans to the mouth of the Arkansas—a distance of about 600 miles. These embankments, in most cases, are maintained by the individual proprietors; so that the security of the property of every planter depends both upon his own vigilance and experience and those of his neighbors. This vigilance is not always sufficient for the protection of the country; and it will hereafter be shown that no care can ever be sufficient to guard against the occurrence of overflows; that breaches through the present levées are unavoidable; and that, indeed, such breaches are the necessary safety-valves for the escape of the surplus water, and must continue to have place until other and less costly provision is made.

The water of the Mississippi now usually rises to a

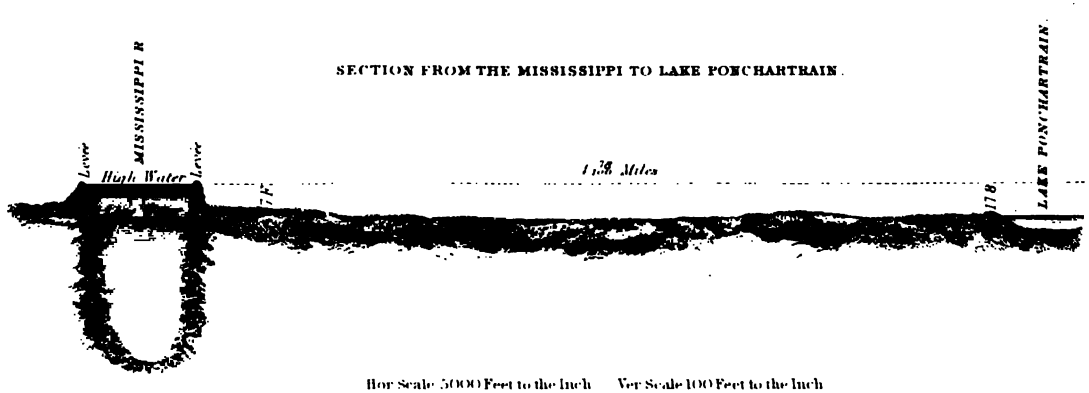
level not more than twelve inches below the tops of the levées, and four or five feet above the general surface of the ground immediately behind the levées. This ground slopes off, at the rate of three or four feet per mile, from the levée to the swamps, or until it reaches a level from fifteen to twenty-five feet below the high-water surface of the river. This is shown in the annexed engraving (Plate III.), which is a correct representation of the four and a half miles extending from the Mississippi at Bonnet Carré, about forty miles above New Orleans, back to Lake Pontchartrain.

If the levée should here give way, as has already happened, the water would, of course, rush through the breach with the velocity due to the depth of the column and the slope of the plane in the rear of the embankment. With a depth of six feet, and a slope of three feet per mile—numbers corresponding with the circumstances of the Bonnet Carré crevasse, as near as any that can now be obtained—the velocity of the current passing from the river into the fields will be, at the surface, by the formula,

$$v = \tfrac{8}{10}\,(3 \times 6)^{\frac{1}{2}} + \frac{3 \times 6}{20} = 4.30 \text{ feet per second.}$$

The area of the Bonnet Carré crevasse, when running, appears by measurement to have been—if we take the entire width of the levée which was destroyed, and the high-water line of the surface while the crevasse was in full activity—about 43,500 square feet. The volume discharged would appear from these elements to be,

$$D = 43{,}500 \times 4.3 \times \tfrac{8}{10} = 149{,}600 \text{ cubic feet per second.}$$


SECTION FROM THE MISSISSIPPI TO LAKE PONCHARTRAIN.
MISSISSIPPI R
Levee
High Water
Levee
17 Ft.
17 Ft.
LAKE PONCHARTRAIN.
Hor Scale 5000 Feet to the Inch
Ver Scale 100 Feet to the Inch

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This is the discharge which we obtain for that great crevasse by using those visible evidences which yet remain. But there is one circumstance which will lead to the conclusion that this crevasse, at no period of its running, gave vent to so great a volume as is deduced from these elements.

A portion of the present gap must have been created after the water had attained its greatest height and had begun to recede; since the current could not have failed to continue to cut away the levée so long as water continued to pass through the opening with sufficient velocity for that purpose. We have no means to determine what deduction should be made on account of the enlargement of the opening during the fall of the water; but it is quite probable that 100,000 cubic feet per second is the extreme estimate to be admitted for the discharge of this crevasse when at its maximum.

Many other crevasses were discharging simultaneously with that of Bonnet Carré during the winter and spring of 1850; but there are no means of ascertaining the total discharge through all these breaches for any portion of that period. It has been estimated by a distinguished engineer of New Orleans, M. Buisson, on the best data that he could obtain, that at one period no less than 536,778 cubic feet per second were drawn off laterally by the crevasses of that year. But, as this estimate seems to have been made by using the actual breadth of the opening, as it was measured after the flood had subsided, it is probably in excess—a part of the breach

having doubtless been created during the fall of the water.

But, if we make the most liberal allowance for this consideration, and assume that one-half of the total width of opening was produced during the subsidence of the waters, we shall still have a discharge of nearly 300,000 cubic feet per second for the crevasses of 1850, resulting from the facts exhibited by M. Buisson.

It is, however, quite impossible now to ascertain the discharge of the crevasses of past years with any approach to certainty. But in 1851, when there was no remarkable flood in the Mississippi, the writer had the means of making an approximate estimate of the volume discharged by all the crevasses then in activity below the mouth of Red River.

To arrive at this volume, an attempt was made to measure the discharge of the Mississippi River below the mouth of Red River, the lowest of its tributaries, and again below all the crevasses at the time of extreme high water. Then, by taking the difference between these results, it was hoped to obtain an expression for the volume lost by the way. But impediments to the perfect execution of this plan occurred, and the water had receded somewhat, at both points, from its highest mark, before the measurements could be completed. We are obliged, therefore, to make some allowance for this fall, in order to obtain the true discharge at either point.

The following are the results deduced from the measurements, and corrected for the subsidence of the river:—

The discharge of the Mississippi, below the mouth of Red River, per second, at the top of the flood of 1851, was	1,134,500 cub. ft.
The discharge below New Orleans, during the high water of 1851, was	995,000 "
Lost between Red River and the place of observation, eleven miles below New Orleans . .	139,500 cub. ft.

This loss is attributable partly to the discharge of the crevasses below Red River, and partly to that of the two natural outlets, the bayous Plaquemine and La Fourche, which are still in activity.

The high-water discharge of the Plaquemine, per second, was found by gauging to be . . .	28,500 cub. ft.
That of the La Fourche	10,200 "
Total discharge of the two natural outlets . .	38,700 cub. ft.

Now, by deducting the discharge of these two natural outlets, from the above total loss of water between the mouth of Red River and a point eleven miles below New Orleans, we obtain the discharge of all the crevasses at the time of the extreme high water of 1851. This discharge was 100,800 cubic feet per second. Neglecting the fraction, we may assume that in 1851 a volume equal to 100,000 cubic feet per second, or about ten per cent. of the total discharge of the Mississippi at New Orleans, escaped from the channel, and passed through the vents in the artificial levées below Red River.

These measurements were made in the best possible conditions of wind and weather; and though all such computations and measurements are liable to some error,

it is believed that these may be relied on as accurate enough for any practical deductions which it may be desirable to draw from them.

But, we have already seen that if the volume discharged by the river at high water were increased 35,000 cubic feet per second, the surface would be raised below Red River about one foot. We cannot, however, thence conclude, that if the crevasses which, as we have seen, discharged 100,000 cubic feet per second, had been all closed up, the water would have risen, at any point, within a fraction of three feet. These crevasses were distributed all along the coast, and many of them were too far below Red River to affect the height of the floods materially there; while an increase of more than 35,000 cubic feet per second would be required to raise the surface twelve inches at New Orleans. It is, indeed, impossible to say with certainty what would have been precisely the increased height of the flood of 1851, at any point, if the levées below Red River had been high enough and strong enough to support the weight of the water which was upon them. The writer can only express the opinion, the correctness of which he cannot fully demonstrate, that if the levées had withstood the pressure, the flood of this year would have been about two feet higher at and near Baton Rouge, than the line which it actually attained; and, consequently, if the crevasses had not occurred to vent the water, the levées of lower Louisiana, which were only ten or twelve inches above the flood, must have been generally overflowed. It follows, therefore, that if it be determined

hereafter to rely exclusively on levées, and prevent the occurrence of crevasses altogether, these levées, to sustain a flood like that of 1851, must be made, from Red River to New Orleans, competent to resist an increase of ten per cent. in the volume discharged by the river; or, in the view of the writer, at least two feet higher than the present banks. This condition, it is apparent, would involve the entire reconstruction of the embankments on both sides of the river; and hence, *in order to retain merely the crevasse-water of this year*, the levées must be entirely reconstructed, and made two feet higher; or new outlets must be opened, competent to vent 100,000 cubic feet per second—which is more than the volume now drawn from the Mississippi, at high water, by the Atchafalaya itself.

LOCAL CHANGES AND IRREGULARITIES.

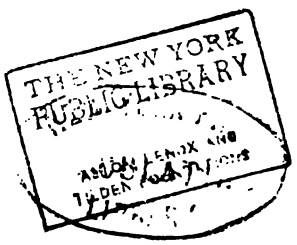
Close observers of the Mississippi sometimes remark singular and often inexplicable phenomena attending its floods and movements; and, in consequence of the insufficiency of the facts which are known, to account for the observed irregularities, it is customary to regard this river as a river *sui generis;* which sets at defiance the acknowledged laws of hydrodynamics, and disappoints all calculations based on recognized principles. But these irregularities are always traceable to some sufficient cause, when carefully investigated, and all the attendant facts are elicited.

A CREVASSE will frequently produce a material depres-

sion at the point where it occurs, and also both above and below that point. If this crevasse happen to be closed up before the next flood approaches, there will, of course, be an apparent rise in the water where the previous depression had been observed.

A NEW LEVEE, which excludes the water from a large area of swamp previously filled by the overflows, will cause an engorgement of the stream at that point, and a consequent rise, which will extend over a considerable space above and below the new work.

The BENDS of the river, as has been shown, cause its surface to assume a distorted shape. Where the water impinges against the concave shore of a bend, its surface rises a certain amount—the height due to the velocity of impact. But the tendency of the stream is forever to elongate its channel, and make compensating deposits on the salient angles. These points sometimes undergo material changes of position. Sandbars are washed away from the jutting angles in some cases, and new deposits are formed in other positions. The current, consequently, impinges afterward against a bank where there was formerly an eddy, and the slope of the surface was up stream. The direction of the current being thus reversed, there will necessarily be a change in the high-water mark produced by an equal flood; which may, in extreme cases, under like circumstances in other respects, be almost equal to the sums of the heights due to the reversed velocities. From this cause alone, having its origin in the tortuous course of the stream, there must occasionally occur local changes of more than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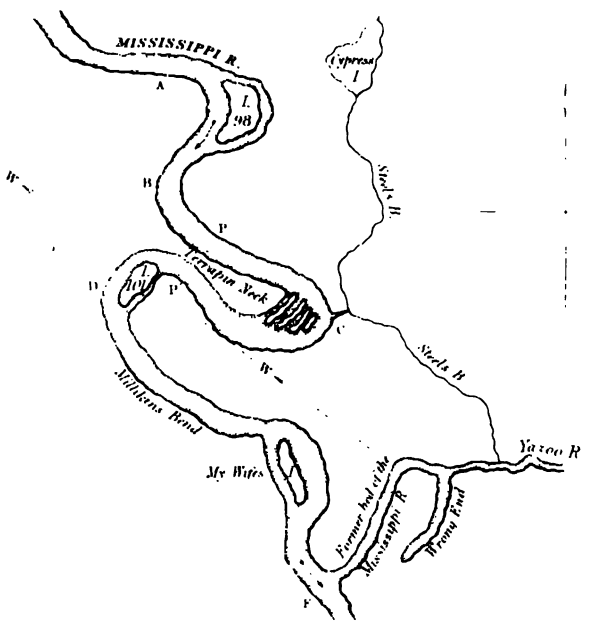
MISSISSIPPI RIVER AT MILLIKIN'S BEND.



twelve inches in the heights of equal floods, or floods produced by equal volumes of water.

The WIND is another fruitful source of local irregularities. A prevailing breeze in a given direction might produce results which would defy speculation, unless its effects were investigated as a distinct study, with the aid of correct maps of the river.

The writer once had an opportunity, in running a test-level along both shores of the Chautauque Lake, a narrow sheet of water, to detect a variation in the surface, of more than eight inches in twenty miles, produced entirely by a continued but moderate breeze. Indeed, such effects are of daily observation on all lakes and tide-water streams. But in the channel of a winding river, like the Mississippi, they are much greater than in ordinary cases, and much more difficult of detection. The same wind that increases the height of a flood in one bend will reduce its height in the next; so that while the flood at a given point is even with the flood of a previous year, it may be found at some place a few miles distant, under circumstances precisely similar in other respects, many inches higher or lower than the mark of the previous flood.

This may be readily explained by a diagram (Plate IV.), which is taken from La Tourette's map of *Millikin's Bend*, above the mouth of the Yazoo.

Here the course of the Mississippi is descending from A to F. The arrows WW, represent the direction of the wind. The effect of this breeze, acting upon the surface of the water along the reach from E to D, will

be to retard its flow and cause an accumulation in the bend at D; while at the same time the effect of the same breeze, acting along the reach from C to D, will be to hasten the surface forward and increase the accumulation at the same point—in the bend D.

But, in the mean time, this same current of air, driving the surface-water forward from C to D, pushes it also back from C, in the reach BC, and tends to retain it at B. The water is thus driven away from C, along both the channels CB and CD, while it is driven forward by the same wind to D, along both the channels CD and ED. The consequence will be, that, while this wind prevails, there will be a decided accumulation of water at D, and a material reduction of the surface at C. The floods at these points will not correspond in height with a previous flood when the direction of the wind was different, and much less if its direction in the previous flood were reversed.

In a river as tortuous as the Mississippi, every wind that blows, no matter what may be its direction, must produce such discrepancies in some parts of its course. And in constructing a profile of two consecutive floods, as has been attempted for the floods of 1850 and 1851, in this paper, we must not be surprised if we sometimes encounter, in close investigations, singular anomalies.

The SMALLER TRIBUTARIES are also, frequently, the cause of such irregularities as are here under consideration. A very inconsiderable stream, discharging suddenly for a few days, or hours even, a large volume into a full river, will produce a material elevation as well

above as below the mouth of the tributary. Consequently, before attempting to explain the cause of a local variation in consecutive floods, we must know the condition of the nearest of the important tributaries at the respective periods.

It is not the intention here, however, to enter into a minute discussion of the uninteresting and almost useless details of the recent floods in the lower Mississippi. The great object before us—to contrive measures for the protection of the delta from overflow—is not to be attained by a microscopic examination of such local phenomena. The solution of this problem turns upon other and greater elements, which we are now in a position to discuss with profit. The first step in seeking a practical result is, to determine with certainty the prominent causes of the increasing inundations, and to obtain the means of estimating correctly the respective values of such causes.

PART II.

CAUSES OF THE INCREASING OVERFLOWS OF THE MISSISSIPPI.

THE object of the investigations which have been ordered, of the condition of the delta, is to decide upon some appropriate mode of protecting the country against the annual inundations of the river. To be able to provide a remedy for this great evil, it is necessary, in advance, to satisfy the mind of the causes which produce the evil. These causes, it will now be shown, are essentially *artificial*. The floods are increased in frequency and in height by artificial means, and it is not unreasonable, therefore, to look for relief to artificial appliances.

Of the various influences to which the increasing elevation of the recent floods of the Mississippi is to be referred, there is but one that can be regarded as belonging to the class of *natural causes*. This exception will be considered first.

OF THE PROLONGATION OF THE DELTA.

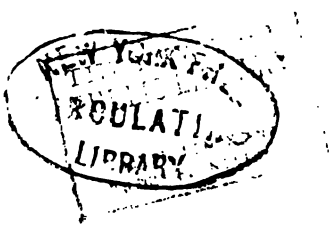
It is a popular belief that the bed of the Mississippi is gradually *rising*, and to that assumed cause is not unfrequently attributed the constantly increasing height

required for the protecting levées. But this belief can be traced to no better evidence than the fact, that certain points, which formerly exhibited deep soundings, have subsequently become shallower—a circumstance which is attributable altogether to the shifting nature of the shores and bottom of the river. As consequences of the changing and movable character of the soil through which the Mississippi flows, shores which are at one period curved, subsequently become salient; banks that at one time wash and cave in, at a later date fill up; places which, during one period, are gradually growing deeper, at another become less deep, and to the sounding-line indicate an elevation of the bottom. There is, in fact, no evidence of any change in the general level of the river's bed, beyond what may be inferred from the evident prolongation of the delta, the lengthening out of the course of the stream, and the consequent diminution of the plane of descent. But this elevation of the bed is not indicated by any increased depth of the stream, though it must of necessity occasion a corresponding elevation of the surface. Any increase in the height of the floods, produced by a given body of water discharged in a given time, beyond what may be justly attributed to this extension of the delta, must, therefore, be sought in other adequate causes.

It is important, then, to ascertain what influence the progress of the land into the gulf may have upon this question, in order to be able to judge of the ability of society to contend permanently against this, the only visible natural cause of increasing overflows. This is a

subject upon which we are compelled to reason without the aid of precise and satisfactory data. The writer is unwilling to admit a mere speculation in this paper, but in the present case it cannot well be avoided.

At whatever point we place the original head of the delta, at the time when the sea flowed up to that point, there must have been a fall in the Mississippi there, or in that vicinity, equal to the whole descent from the present level of the river at that place to the level of the ocean. Now, the first chain of rock which is supposed to form the bed of the Mississippi, is found at the village of Commerce, about thirty miles above the mouth of the Ohio, where the rocky hills approach the shore on both sides of the river, and are said to be connected by a bed of rock in the bottom of the channel. The low-water surface of the river at this "Chain," is about two hundred and eighty-five feet above the Gulf of Mexico. It follows, therefore, that if, at the period when the formation of the delta may be supposed to have commenced, the level of these rocky hills and the level of the ocean were the same as they are now, there must have been, as before stated, a *cataract*, or rapids, above the mouth of the Ohio, with a fall of two hundred and eighty-five feet at low water, or nearly double the actual perpendicular descent of the Falls of Niagara. The water of the Mississippi must have plunged over this cataract, or over great rapids, directly into the sea, which, by the supposition, then flowed up beyond the mouth of the Ohio. In the course of time, the sea must have been filled up by the sediment brought down by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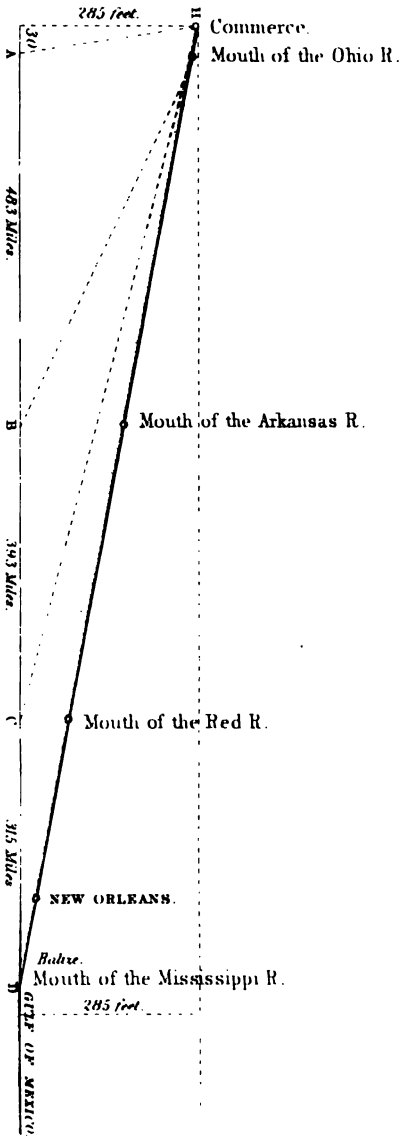
285 feet.
H
Commerce.
Mouth of the Ohio R.
A
483 Miles.
B
Mouth of the Arkansas R.
343 Miles.
C
Mouth of the Red R.
315 Miles.
NEW ORLEANS.
Balize.
D
Mouth of the Mississippi R.
285 feet.
GULF OF MEXICO

Plate 5

the Mississippi River; and the Mississippi has thus gradually risen upon the bed formed by its own deposits.

As the deposit has been pushed out into the sea, the slope of the river has progressively diminished; and as the slope of the plane has diminished, the surface of the river has risen, and the bottom, of course, has also been in like manner elevated.

It is not contended here that the true head of the delta is demonstrably to be found above the mouth of the Ohio. It is quite possible that there were great rapids only here, and other rapids nearer the sea, at one or more points lower down the stream. The force of the argument which is made will not be in the least impaired by an erroneous location of the original head of the delta, and it is no part of the present purpose to engage in irrelevant geological speculations.

It will be assumed, therefore, that the head of the delta was once above the mouth of the Ohio, where the soil is now about 285 feet above the level of the sea; and that the depth of the sea was then about the same where the delta now is, as the present depth of the Gulf of Mexico within a few miles of the Belize: that since that period the delta has been formed by the annual accumulation of sediment brought down by the stream and deposited in the sea. The inevitable consequence of this hypothesis, will then be, that the slope of the plane must have been, at successive periods, as represented in the annexed diagram, (Plate V.)

Originally, or at some period anterior to the formation of the delta, the river sloped off abruptly, forming

a cataract or rapids, from the hills at Commerce to the point A; subsequently, the whole space embraced in the triangle H A B, became filled up by sedimentary accretions, and the river sloped off from H to the mouth of the Arkansas, with a descent represented by H B, more than twice as great as its present rate of descent. By degrees, and in the course of ages, these accumulations reached the mouth of Red River, at C; and, in more modern periods, were extended on to the present shores of the gulf, at D.

It is manifest, therefore, that while this process is going forward, the surface of the river must be rising, and that, as the surface is elevated, the bottom must also simultaneously rise. In fact, it is the elevation of the bed which causes the rise of the surface.

Nothing can be more palpable than the gradual elevation of the surface of the Mississippi, in so far as it is attributable to this cause; and it is therefore most manifest that, while the river is thus rising above the sea, and the levées so confine the water to the channel as to prevent simultaneous deposits upon its borders, the floods will gain both upon the natural and artificial banks, and *ultimately* overtop them.

To this extent, it must be admitted that the rise of the bed of the river will forever be a cause of increasing inundations. But it remains for us to ascertain whether this cause can be sufficient to account for any portion of the present sufferings of the population of the delta, or whether its operation has not been too slow even for detection within historical periods.

The area of the delta is not accurately known, but it will be estimated in this report, in the absence of data from which to make a more accurate approximation, at forty thousand square miles.

It is known from actual survey, that the mouth of the Ohio, at low water, is two hundred and seventy-five feet above the level of the sea; and it has been ascertained by the levels taken under the direction of the writer, that the slope of the Mississippi, near the mouth of the Ohio, is about five inches per mile. (See note D.) The total elevation, then, at Commerce, is, as stated, very nearly two hundred and eighty-five feet above the sea. Adding, for the average height of the banks, thirty-five feet, we have three hundred and twenty feet for the level of the Mississippi bottoms near Commerce, above that of the Gulf of Mexico. But, as the plane of the delta slopes off gradually and uniformly from this village to the gulf, the average level of the whole area will be but about one-half of this height, or one hundred and sixty feet above the sea; and if we should make a reasonable allowance for the greater breadth of the plane near the sea, than nearer its head, it is probable that 140 feet would be found to be a very fair estimate of the average depth of the whole deposit above the level of the tide.

Now, it has been found by the experiments of Professor Riddell, at New Orleans, conducted with great care and often repeated, that the mean bulk of sedimentary matter transported by this river, when solidified into coherent earth, is about $\frac{1}{3000}$ part of the volume of the

water in which it is suspended. If, now, superadded to these data, we could obtain the total annual discharge of the Mississippi and its tributaries, we would command all the facts necessary to compute approximately the amount of the annual deposits brought down by the current. But there are no sufficient observations to enable us to estimate the total discharge of the Mississippi and its outlets for any one year. This volume has been estimated by Professor Forshey, from numerous observations of his own, made through a long series of years, at an average of 12,250,000,000,000 cubic feet; and for the year 1849 at 13,338,040,000,000 cubic feet; and these estimates have been adopted by numerous engineers who have discussed the great problem of controlling the Mississippi. But, though the period embraced by the investigations upon which this memoir is founded did not permit an attempt to estimate the aggregate annual drainage of the Mississippi valley, with any approach to accuracy, the observations which were made are, nevertheless, sufficient to justify the conclusion that the discharge of the Mississippi and its natural outlets, when fully ascertained, will be found to average at least fifty per cent. more than the received estimate, or probably not less than

21,000,000,000,000 cubic feet per annum.

This volume, though by no means regarded as accurate, will be assumed as the basis of the conclusions to be drawn in the matter before us, where great precision is not at all needed.

Now, it has already been stated, on the authority of an accomplished manipulator (Professor Riddell), that the $\frac{1}{1000}$ part of the total annual discharge of the river consists of sedimentary matter. Whence we find, for the annual deposit of sediment, or the volume annually left in the gulf at or near the mouth of the Mississippi,

7,000,000,000 cubic feet.

This mass of material would be sufficient to raise, to the height of one hundred and forty feet, a portion of the delta equal to $1\frac{8}{10}$ square miles. To form the whole delta, or that portion thereof which is now above the sea—covering, as estimated, 40,000 square miles—would then have required a period of

$$\frac{40000}{1.8} = 22{,}222 \text{ years.}$$

This result is, of course, based upon the supposition that this vast formation is the product of the agencies now at work—the visible causes now in action.

If the delta has resulted from the deposits of the river, then it is demonstrated from these facts—not minutely ascertained, but, nevertheless, near enough to positive accuracy for any desirable practical conclusion—that more than 20,000 years must have been occupied in the formation of that portion thereof which is now above the plane of the sea.

But it is known that, when we proceed a few leagues out into the gulf, we find soundings of more than fifty fathoms, and, over extensive portions of its area, of more than one thousand feet. Though we cannot prove

that this, or any other given depth was originally maintained up to the assumed head of the delta, it is, nevertheless, not an unreasonable supposition that, at periods anterior to the commencement of the deposit, the bed of the gulf sloped up uniformly from its present depth, near the Belize, to the shores then found above the mouth of the Ohio. This under-water deposit must, therefore, have required a mass of matter more than equal in volume to that now found above the surface of the ocean. Hence we are authorized to conclude that the total formation known as the delta of the Mississippi, if it be, as is scarcely deniable, the result of sedimentary precipitation, has required a period for its formation by the river of something like 45,000 years.

Now the average length of the delta, from north to south, is about five hundred miles; and, if its total formation has required a period of 45,000 years, each mile of the progress of its shore into the sea has consumed an average period of

$$\frac{45000}{500} = 90 \text{ years.}$$

This is to be regarded as an extreme estimate, of the average march of the whole coast, southwardly, from the beginning of the deposit; but it is certain that the progress of the entire front, in later periods, must have been much less rapid, both in consequence of the increase of the depth of the gulf as we proceed towards its centre, and the greater longitude of the coast, which has, in modern days, been advancing seaward.

It will be observed that this result applies to the

extension of the whole gulf shore, from the mouth of Pearl River to Vermillion Bay, in a southwardly direction. But, immediately at the point where the Mississippi enters the gulf, it pushes out a narrow peninsula, with numerous mouths, and for a period makes its deposits opposite to these mouths, and laterally therefrom, to only a very limited distance on either side. While it occupies this position, as at the present period of its history, and while all the material which it bears is used in forming this narrow peninsula, the apparent progress of the land upon the sea is much greater than the actual average advancement of the whole front of the delta—which can only be set forward by the shifting of the immediate mouths of the river.

There appears to be plausible evidence of a present local progress of the immediate embouchure of the Mississippi, of not less than one mile in twenty years, showing a probable local or limited march four or five times as great as the average progress deduced above for the whole front from remote periods.

Now, it is this local progress which marks the present rate of elevation of the bed of the Mississippi.

The level of the river at New Orleans, in times of flood, may be stated to be 13.5 feet above mean tide, and the distance from the city to the gulf at 105 miles.

The average slope of the river from New Orleans to its mouth, at high water, is, therefore,

$$\frac{13.5}{105} = .128 \text{ of a foot, or } 1\tfrac{1}{2} \text{ inch per mile.}$$

If that same average slope be maintained as the mouth of the river moves forward—which it will be,

very nearly—each mile that the land gains from the sea will involve an elevation of 1½ inch in the high-water surface, and, consequently, in the bed of the river at New Orleans. This will produce an elevation—while the Mississippi continues to discharge at its present embouchure—of about 7½ inches in the course of a century; which is certainly an extreme estimate.

It is sometimes conjectured that the city of New Orleans is destined to ultimate destruction from the gradual, and, as it is supposed, the visible rise of the bottom of the river. But it is not easy to detect the danger in any agency to which the assumed catastrophe has ever yet been attributed. There is, in fact, no presumable rise of the bed of the river, but that which is referable to this one cause—the gradual extension of the delta.

The idea which has acquired a certain hold upon public opinion, that an appreciable elevation of the bed of the Mississippi has been produced, and is still going forward, in consequence of the extension of the levées, has no foundation in experience or philosophic deduction. The extension of the levées, it will be hereafter shown, exercises great influence upon the height of the floods; but not, as is supposed, by raising the bed of the river. It is true that, by the increased transporting power which the levées give to the river, and by their prevention of lateral deposits, the Mississippi is enabled to convey greater deposits into the gulf; and thus, in some slight degree, accelerate the formation of land opposite its mouths. To this amount, and no further,

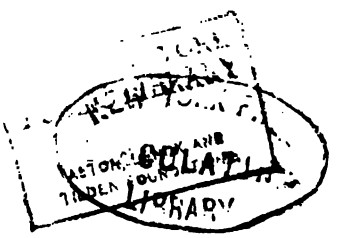

Plate 6.

the extension of the levées may promote the elevation of the river's bed; but this is not an appreciable quantity.

It is customary to point to the Po, in evidence of the effect of embanking the coasts of streams in producing an elevation of the bed of the river. And it is assumed that, because the bottom of that stream has been greatly elevated since levées were there commenced, the obvious rise of its bed is directly attributable to the levées. But the true cause of the rapid elevation of the bottom of the Po, and of all the rivers that empty into the Adriatic, is to be found in the great quantity of earthy matter which they transport to the sea, and the shallowness of the gulf into which this material is conveyed. This deposit, in the course of twenty centuries, has produced a prolongation of the delta of the Po, estimated at about twenty-five miles, and has converted cities, which, at the commencement of the Christian era, were respectable seaports, into inland towns, at this day twenty miles from the sea-shore.

If we now assume that the town of Ferrara is about fifty miles from the coast, and that the slope of the Po, in high water, from Ferrara to the gulf, is seven inches per mile, we shall perceive how an extension of the delta twenty miles into the gulf will have brought the tops of the levées above the roofs of the houses in that city.

In the annexed engraving (Plate VI.), F represents the position of Ferrara, on the Po, as it was twenty centuries ago; M, the mouth of the river, or the shore of the Adriatic at that period; and M′, the position of

the shore at this time—MM′ representing the progress of the delta in the course of two thousand years.

It is obvious, from the figure, that M *n* will represent the elevation of the bed, or the present height of the surface of the river, above the level of the sea at the ancient shore of the Adriatic. And, if the descent of the Po is now about seven inches per mile, this elevation must be twelve or fourteen feet, and very nearly the same at Ferrara.

If we now add twelve feet to the height of the embankment originally required to protect the ancient town from the floods, we shall perceive that the present levées must necessarily be level with, or above, the roofs of the smaller class of houses in the modern city.

In the course of twenty centuries, in consequence of the prolongation of the delta of the Mississippi, no doubt the levées required to protect the city of New Orleans will have risen to a great height there also—probably to a height of ten or twelve feet above the actual plane of the streets—unless the river, deserting its present bed below the city, should form a new outlet into Lake Borgne, and transfer its sedimentary deposits into the deep water of the gulf south and east of Ship Island. This is a consummation, as we shall presently see, much to be desired.

But it is not those effects that may be witnessed in the course of centuries which it is the intention now to discuss. The actual rate of progress of the delta will soon be solved, approximately, by the coast survey, and we shall then have all the material for speculation

upon the future geological changes liable to have place in consequence of the prolongation of the peninsula at the mouths of the Mississippi. The present inquiry will be limited entirely to those evils which at this moment threaten the prosperity and existence of lower Louisiana, and the worst effects of which are likely to be witnessed by men now living. The elevation of the bed of the river, consequent on the progress of the delta, is clearly not one of these. That is too slow to concern the present generation.

It is not to the gradual but certain work of nature, in filling up the sea by the deposits brought down from the plains and mountains, that the increasing height of the floods now felt is to be attributed. These, we shall find, are traceable directly to the labors of men, long and still vigorously engaged in draining the waters, by various processes, more rapidly from the country above, and destroying those natural reservoirs which originally protected the country below.

OF THE CUT-OFFS.

Among the causes of the inundations that have recently produced so much loss and distress on the lower Mississippi, in the opinion of the writer, must be enumerated the *cut-offs* which have been made at and below the mouth of Red River. It is true that men of science have denied, and do still contest this point. But the opinion here entertained rests on what are deemed to be the natural laws of the flow of the river,

and, moreover, on indisputable results. The theory which is entertained by many intelligent persons, that, by shortening the channel and cutting off the bends of the river, the velocity of the current will be increased, the channel scoured out wider and deeper, the floods conveyed more rapidly to the sea, and the surface, therefore, reduced, is all perfectly true, excepting the practical conclusion.

It is true that, by cutting off a given bend, the flood will be hastened forward, and a greater volume will, therefore, be discharged through the channel in a given time. But it will not be discharged directly into the sea, and thus relieve the river of its burden. On the contrary, the water will be drawn more rapidly from the river above the bend, and the level of the surface there will be reduced; *but it will be precipitated more rapidly into the river below the bend*, and the surface there will be necessarily raised. This is precisely the error which led the State of Louisiana, in face of the sound advice of several eminent engineers, into the unfortunate experiment of cutting off the Raccourci Bend in 1848.* The velocity of the river, it was contended, would be increased, and the height of the floods, therefore, reduced. They were reduced *above* the bend, from whence the water was more rapidly drawn; but

* It is due to Colonel William S. Campbell, civil engineer, to say, that he constantly resisted this work, before the legislature; and to Colonel P. A. Hebert, at that time the chief-engineer of Louisiana, to record that he also opposed it as long and as warmly as an officer of the State government could oppose the will of the legislature.

they were increased *below* the bend, where it was more rapidly thrown.

The reason in favor of shortening the channel would have been sound if it had been proposed to cut off a part of the lower portions of the river, as will be proposed hereafter in this paper, and admit the water into the gulf at some point further from the sea than its present mouths. The effect of such a course may be appreciated by the annexed diagram (Plate VII., Fig. 1).

Let M′ be the present mouth of the river, near the Belize, and S′ M′ the present slope of the surface of the stream at high water.

If we cut through the natural levée which now confines the flood, and let the river into the gulf at M, fifty miles higher up, we shall obviously reduce the surface at M an amount equal to M *m*—the whole of the descent in the lower fifty miles of the river, or about six feet. The surface of the river will then be found along the new line S M, *below* that which marks its present slope.

But a very different state of facts results from cutting off a bend of the river in the upper portions of its course. The Mississippi descends from the head of the delta to the head of tide in obedience to what may be designated as *the law of uniform descent.* The plane upon which it rests slopes down to the ocean, as already shown, at the average of eight inches per mile. But the Mississippi flows on tranquilly and smoothly, in whatever direction it chances to take, seeking every point of the compass—sometimes parallel with, and

sometimes at right angles to the plane which supports it; sometimes directly down that plane, and sometimes in a direction directly opposed to that of its descent; but always with the same almost uniform and unbroken slope. That slope averages at high water a little over 3½ inches per mile, from the mouth of the Ohio to the vicinity of the tidal influence.* There are of course local irregularities, caused by the great flexures of the river, and by sandbars, which produce occasional acceleration, and even littoral *inversions* of the current; but these are local and limited influences, and can scarcely be regarded as exceptions to the general law of the river's motion.

Now, when a great bend is cut off, as at Raccourci, below Red River, the total descent around the bend—which was in this case 4½ feet at high water—is suddenly concentrated in the narrow neck, of less than one mile, across the bend. The moment when the cut-off is made, therefore, the slope of the river will assume the form represented in the diagram below.

Here the fall from *a* to *b*, a distance of one mile across the neck of the bend, is four and a half feet, and consequently the water rushes through the artificial opening, with a speed due to that descent, and to the depth of the new channel. (See Plate VII., Fig. 2.)

A few days suffices to wear away the soft material which confines the water, and the reach of the river

* In this, as in all other computations, the writer is compelled to adopt the distances as reckoned by the river pilots.

Fig 1.

Fig 2.

Plate 7

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TILDEN FOUNDATIONS

above is rapidly drained off in some degree, by the increased descent of the surface, and discharged into the reach below. The new surface, therefore, speedily assumes the slope of the line a' b'—the excess drawn from above being deposited below. The increased draft through the cut-off thus draining the river above more rapidly than it was accustomed to discharge itself around the curve, the surplus water is necessarily thrown into the river below more rapidly than the channel there had been accustomed to receive and discharge it. The consequence of this increase of supply must, obviously, be a sufficient accumulation below the cut to produce that increase of depth and speed which is necessary to enable the channel there to vent the additional supply sent down, as fast as it is received.

The writer is aware that there is, along the Mississippi, a prevailing opinion in favor of cutting off the great bends and shortening the channel. The interests of the navigation, and of those who depend on the navigation, seem to be promoted by it. But this is an *improvement* of the most dangerous description—one of those things which can be accomplished easily, and without skill, and therefore always liable to be attempted. Besides, experience has shown conclusively that after a cut-off has been made, the lands above are rendered less subject to inundation than they were before, and there is consequently a strong interest always ready to encourage an enterprise that will bring certain relief to a few, even though it may be contended that this

relief to them will be disastrous to their neighbors. They contest this fact on the authority of scientific writers; and the minds of men are easily convinced of the soundness of arguments which it is their interest to sustain.

We cannot hope to relieve ourselves of the sad effects of these violent changes of the course of the river, by the method proposed in a late report to the Commissioner of the Land-Office,* viz., to commence at the Gulf of Mexico, and straighten the river from the sea towards its source; nor by the other suggestion of compensating for the increased volume poured down through the cut-off above, by making additional cut-offs below, and thus hastening the drainage of the reach below the upper cut-off. There is no opportunity offered by the bends of the Mississippi for any such compensation. The only cut-offs that can hereafter be made with any show of caution are above Red River, and all that are made there will tend to precipitate the water more rapidly upon the beautiful estates which stretch from Natchez to the sea.

The increase of the velocity of the current below the cut-offs, in virtue of the reduction of the length of the channel, cannot prevent the increase of the floods, by giving more rapid vent to the water—for this acceleration is itself only a consequence of the increased elevation of the surface produced by the additional supply.

For these reasons the writer deemed it expedient to

* Ex. Doc. No. 68, Senate, 31st Congress, 1st session.

examine those bends of the river which seem to offer the greatest facilities for the making of cut-offs, either natural or artificial, with a view to ascertain what measures, if any, were needed to prevent their occurrence by the direct working of the river, or by design.

The points to which attention was specially directed, and the general results of the examinations instituted, will be exhibited in this paper. It may be well to state here, however, that one of these points, the Terrapin Neck Bend, above Vicksburg, requires immediate attention, to prevent the occurrence of a sudden cut-off, and the overflow, to some extent, of many valuable estates below it.

OF THE EFFECTS OF CULTIVATION.

Among the causes contributing to the increase of floods in the rivers of the United States in recent years, it is necessary to include an increased discharge of water due to the destruction of the timber, and the cultivation of territory which was formerly untilled. It is reasonable to suppose that the removal of the forest growth, and the rank vegetation of the virgin soil, will cause the slopes to shed the rain more rapidly into the valleys, and thus produce more sudden and more violent floods than were observed of old.

Indeed, it cannot well be denied that this result must spring from this cause. But it is not to be overlooked that, at the same time, the removal of the timber gives the sun's rays more direct access to the earth, and thus

promotes an increase of evaporation. This increase of evaporation is, of course, at the expense of the drainage; for, as the evaporation increases, the volume of water that finds its way into the streams is necessarily diminished. The effect of clearing the soil of its original growth is thus, at once, to develop two opposite and compensating influences. But it can scarcely be doubted that, as a rule of almost general application, the resultant of these influences will, in the aggregate, be in favor of a great increase of the discharge of the streams, and a material reduction of the evaporation.

But, be this as it may, it is very obvious that the height of the floods must be increased by the extension of cultivation and improvement. The increase of evaporation consequent on the exposure of the surface of the earth to the rays of the sun, has place mainly when the sun possesses the greatest power—in the summer season. The effect of clearing the soil of vegetation will, therefore, be to diminish the summer volume, and consequently further to impair the low-water navigation of the streams. But, in winter, when the power of the sun and the resulting evaporation are small, and the rain and snow rest long on the prairies, the necessary effect of removing the timber will be to increase the drainage.

It may therefore be asserted generally, that the effect of cultivation is to increase the evaporation in the summer months, and thus reduce the summer drainage; and to hasten and augment the drainage in the winter

months, and consequently increase the height and power of the floods. In short, the clearing of the soil tends constantly to make the water lower in the summer and fall, and the floods higher in the winter and spring.

The area of the Mississippi valley is composed, in the main, of wide extended plains and level prairies, on which, in the original condition of the country, there was little or no timber. Over these plains, the water which falls on the untilled soil is obstructed by the wild grass and bushes, and consequently retained upon the flat surface until it is either evaporated, or slowly passes off into the natural depressions, which convey it through similar impediments to the greater channels of discharge.

But, as population takes possession of the ground, the wild grass is removed, and the plough is applied to the drainage. The primitive furrows are so directed as to let off the surface-water; and the imperfect drains first opened by the plough, are subsequently enlarged and made the channels into which the lateral ditches are led. The success of the crop depends on the perfection of the drainage; and, consequently, one of the first efforts of every provident farmer, on breaking up the sod, is to relieve the surface of his fields of standing water. But the water rapidly discharged from these incipient drains meets with impediments in the choked up streams, is held back by fallen timber, and spreads over the bottom land. To save these narrow strips of bottom land, which generally afford the finest pastures,

the industrious husbandman promptly removes these obstructions from the channel and lets the water off into the country below.

This process, though in reality hardly well commenced, is yet progressing over the valley of the Mississippi at the rate of many millions of acres annually. The aim of every proprietor is to drain his own fields, and let the water pass as rapidly as possible into the creeks and rivulets which are provided by nature to convey it away. But the land upon the great tributaries into which this water passes, is equally valuable; and each proprietor there fortifies himself in like manner against the annual and increasing flood. He also drains his fields with a view to the more rapid discharge of the surface-water; throws up embankments across the low places to shut out the flood; and, if the circumstances of his situation will justify it, levees in his front and confines the swollen water to the actual channel of the stream.

The immediate consequence of all this is, that the water, which, in the original condition of the country, remained upon the surface of the prairies until a portion was evaporated, and a portion absorbed by the earth, to be subsequently given out slowly by the springs, is now hurried along hundreds of thousands of artificial drains into the great rivers which supply the Mississippi.

The effect of cultivation is, therefore, to cause a necessary increase of drainage from all the unwooded prairies of the West. To what extent the floods may

be increased by this cause, we have no data to estimate. Yet it is important to be able to form some idea of the consequence which would result from any supposable increase of the general drainage of the country. For this purpose an attempt has been made to estimate, on the authority of popular maps, the actual area of the valley of the Mississippi, from the source of its distant tributaries down to the mouth of the Red River.

The result of this computation is given below, with the remark merely, that though the areas are expressed as they resulted from the measurements, to the nearest hundred square miles, yet the data from which they are obtained are somewhat uncertain, and the quantities can only be regarded as, at present, the best attainable approximation. The land system of the United States government has not yet been extended to the distant sources of the Mississippi; and, until the surveys have reached the northern and western limits of the Great Valley, we are not likely to have material for a very accurate estimate of its total drainage.

TABLE IV.

OF THE AREAS DRAINED BY THE TRIBUTARIES OF THE MISSISSIPPI RIVER.

	SQ. MILES.
I. THE MISSOURI RIVER.—The area drained by the Missouri and its tributaries is	519,400
II. THE OHIO RIVER.—The area drained by the Ohio and its tributaries is	202,400
III. THE UPPER MISSISSIPPI RIVER.—The area drained by the upper Mississippi, including all the tributaries which come in on the east side above the mouth of the Ohio, and on the west above the mouth of the Missouri, is	184,500
IV. THE ARKANSAS AND WHITE RIVERS.—The area drained by the Arkansas and its tributaries, including White River, is	176,700
V. THE RED RIVER.—The area drained by the Red River and its tributaries is	102,200
VI. THE YAZOO, OBION, BLACK RIVERS, &c.—The area drained by the Yazoo and all other tributaries coming into the Mississippi, on the east side, between the mouth of the Ohio and the mouth of Red River, is	29,300
VII. THE ST. FRANCIS.—The area drained by the St. Francis, embracing the territory lying between its waters and the Mississippi, is	12,100
Total area drained by the Mississippi River above the mouth of Red River	1,226,600

A comparison of these results will show with how much more propriety this great river should have received the name of THE MISSOURI, than that which it bears. The Mississippi, where it runs into the Missouri, is charged with the drainage-water of an area even less than that which supplies the Ohio, and but

little greater than that which is received from the Arkansas and White Rivers.

The Ohio is the greatest of all the tributaries of the Missouri; the upper Mississippi is the next in importance; the Arkansas is the third; and the Red River is the fourth in the scale. The Ohio comes in at, or extremely near, the assumed head of the delta; and, therefore, when the channel immediately below its mouth has been already filled by the discharge from the rivers above, a flood in the Ohio must always produce wide-spread overflow. Yet it is not the Ohio, nor the upper Mississippi, nor even the Missouri, to which the inundations of lower Louisiana are mainly attributable. The water which these upper streams send down is generally absorbed by the swamps or accommodated by the channel of the river. But when this channel is full, or nearly full, and Red River (the fourth in magnitude of the tributaries) pours out a flood, the effect is disastrous to all the country below. In other words, it is almost invariably the tributary which discharges nearest to the point where the overflow occurs that is the immediate cause of ruin. Every observing planter, at or above "The Raft" of Red River, remarks that the floods of the upper Red River itself are nearly always harmless; and that, when the country there suffers, it is not from the waters which have come from the Rocky Mountains, but from Little River and the two Cypresses—streams scarcely known to geography.

These facts are important, because they show that the channels of the great rivers are large enough to

vent the floods which come from their distant sources—the wave of which is spread out and reduced on the way—and that the overflows are occasioned by the simultaneous outpouring of the smaller tributaries discharging into a channel already nearly full. They are further important, because they teach us that, to afford the most prompt relief, we should seek to restrain the Ohio, which enters at the head of the delta, and the Washita and Red Rivers, of which the discharge is so often disastrous to lower Louisiana. We shall hereafter see that those great navigable rivers may be controlled by simply adopting a cheap and easy method of improving their low-water navigation.

Now we have seen that the area drained by the Mississippi is 1,226,600 square miles. Reducing this to feet, we find that the total area of the Mississippi valley is

34,195,645,440,100 square feet.

We have not sufficient data for determining the average annual downfall of rain over all this immense area; but it seems probable, judging from known results, that forty inches will be extremely near to its true value. Assuming that this is the fact—and it can scarcely vary more than two or three inches from the truth—we shall have, for the total annual downfall of water on the whole surface of the Mississippi valley—a downfall which is either carried off by the drainage of the streams or by evaporation—

113,985,484,800,000 cubic feet.

We have not sufficient well-ascertained data to enable us to compare this, the total fall of water in the valley of the Mississippi, with the actual annual discharge of the river. But we have facts enough, obtained in the present investigation, to show that the discharge below Red River, by the Mississippi and its great natural outlet, the Atchafalaya, during sixty days of the high water in the spring of 1851, was 6,225,000,000,000 cubic feet; or at the average rate of

103,750,000,000 cubic feet per diem.

The actual drainage below Red River, during sixty days of the high water of 1851, was, therefore, very nearly the *eighteenth part* of the total annual downfall over the whole area of the Mississippi valley. (See note E.)

If we now divide the volume discharged during the two months of high water in 1851, in cubic feet, by the total area of the valley, in square feet, we shall find, for the value of the drainage during these sixty days—reduced to inches—

$2\frac{18}{100}$ inches.

Now let us suppose, that, from any cause—as the tillage of the prairies, the destruction of the vegetable growth, or the better drainage of the fields—out of the forty inches of rain which falls, *two-fifths* of an inch, or nearly *one per cent.* of the whole, should be discharged into the Mississippi in the course of these sixty days of flood, over and above the present average discharge. If

this slight increase of the total discharge were distributed uniformly over the whole period of sixty days of high water, it would require that the channel of the river should be competent to give vent to an increased volume equal to 220,000 cubic feet per second. If this increased volume be retained within the channel by levées, these levées, according to the conclusions stated at pages 51–2, must be raised about six feet higher than the tops of the present embankments.

The object of this computation is to show how sensitive is the discharge of the river to every variation, however inconsiderable, of the drainage of the country. If the evaporation be slightly reduced, or the drainage slightly hastened or increased, by the causes which are progressing, and which most obviously must produce both effects, then, for every *fifth part of an inch* by which the total drainage is increased in the period of sixty days of usual high water, there must be experienced an average increase *of about three feet* in the height of the floods, unless the water can find its accustomed vent into the swamps. This result may assist the mind in forming some estimate of the consequences which are to spring from the extension of society over the yet unpeopled WEST, and the cultivation of the vast territory which is drained by the Missouri and its tributaries.

OF THE EXTENSION OF THE LEVÉES.

It has already been stated that the recent increase of the height of floods in the lower Mississippi is a result,

not of natural, but of artificial changes. It is true that, in tracing the present or ancient channels of the river, we find deposits in different parts of the delta higher than the present high-water marks, and which stand as incontestable proof that the river, in former ages, was higher, when it left those elevated spots, than the level of the floods which are now witnessed at the same points. These ancient floods may have resulted from an unusual downfall of water, either general or local; or they may have proceeded from an accidental diminution of evaporation, and a corresponding increase of the total drainage. But it is not always necessary to assume that the actual discharge of the river was greater than it is now, to account for the existence of those elevated spots. On the contrary, these places are limited in area, and attributable rather to local than general causes. The whole coast of the Mississippi, from the head of the delta to the gulf, exhibits indubitable evidences of former changes of the river's bed. Old channels are to be found on both sides of the stream, and in all parts of its course, enabling us often to trace the occurrence or to infer the existence of some ancient *cut-off*, which must, in its day, have produced an elevation of the waters below, equal, as has been shown, to about half the total descent around the bend. An ancient cut-off of fifty miles would have produced an elevation of the high-water surface, and consequent deposits below the bend, of more than six feet; and, in process of time, as the river gradually elongated its channel, and approached at that point nearer to its

former condition, its banks, resulting from later deposits, would be found to be five or six feet lower than those ancient traces.

Moreover, it is not contended here that the Mississippi may not, in ancient periods, have occasionally poured larger floods into the ocean than have been witnessed within historical times. A great flood is the result of a simultaneous discharge of the great tributaries, which usually run off successively.

The high water produced by the Red and Arkansas Rivers, in the ordinary course of things, has begun to subside before that of the Ohio, Cumberland, and Tennessee comes down; and these, again, begin to recede before the Mississippi discharges its volume; and this, in its turn, subsides before the snows of the Rocky Mountains, which swell the northern tributaries of the Missouri, are melted by the tardy sun in those high latitudes, and the water has time to flow through the three thousand miles of channel intervening between the sources of those distant streams and the head of the delta. It is a part of the natural order of events, that these great rivers shall discharge successively. But there were doubtless in former ages, as now, exceptions to this natural rule; and a meeting of the flood-waters of distant tributaries may have occurred many times in the course of the tens of thousands of years which have witnessed the formation of the delta. Such things may occur hereafter, and greater floods than have yet been seen by men may be felt along the banks of the Mississippi. But it is not these visitations of Providence

which we have here to discuss and provide for. It is only those most disastrous floods which now so frequently occur, sweeping over the works of industry from year to year, devastating extensive regions, and which are referable to causes that society has created, and is still creating, and which it is, therefore, in the power of society to prevent, that it is our purpose to investigate.

The floods which now carry annual distress and destruction into the lower Mississippi, it is maintained, are essentially the result of artificial causes. The water is supplied by nature, but its *height* is increased by the works of men.

The subordinate causes to which this increase of elevation is attributable, have been sufficiently discussed. The remaining and the prominent cause, it is proposed now to consider. *This cause is the extension of the levées.*

The Mississippi has been, and is still, accustomed to find vent for its surplus waters in the vast swamps which are to be found along the valleys of Red River, the Arkansas, White River, the Yazoo, and the St. Francis; and to the right and left of its proper course, almost the entire distance from Cape Girardeau to the Belize. In the condition of the river, as it still exists above the mouth of the St. Francis, when the surface rises so as to overtop the banks ever so little, the water flows in through the bayous, and down the lateral slopes, and gradually fills up the immense swamps through which the channel winds, and from which it is only separated by the deposit left by pre-

ceding overflows. But each overflow leaves an additional stratum of sediment on the borders of the stream, and raises these belts of elevated soil still higher; and makes also a further deposit of lighter material in the swamps; and, consequently, raises the surface of the swamps in some corresponding degree. The height of the borders of the stream is, therefore, a close guide to the height of the floods to which the deposit is due.

This is now the actual condition of the upper portions of the delta, as it was that of its whole extent when the valley was first occupied by Europeans. The early emigrants found these narrow and elevated borders extremely fertile, and capable of being made immensely productive, by shutting out the floods, which, passing in a thin sheet over the banks, filled up the swamps in the rear of their plantations, and destroyed their crops. With here and there an elevated spot, which was not ordinarily reached by the floods, the whole delta, on both shores, was frequently, if not annually, inundated. A thin column of water passed over the banks along a space of more than a thousand miles on each side of the river, and was received in the vast adjacent low grounds, which served as great reservoirs for the surplus discharged.

In this state of things, each individual planter found it easy to protect his crop, by throwing up a frail embankment along the edge of the river in front of his estate, with wings or lateral banks running back into the swamp.

The rise of the river rarely exceeding the height of

its banks more than a few inches, this slight levée was an efficient protection. But by degrees, and *pari passu* with the progress of society, these levées were extended from the lowest points of tillable land, near the gulf, up both shores of the river, until they now reach, in an almost unbroken line, beyond the mouth of the Arkansas; and are to be found at intervals as high up as Memphis. These works were originally commenced for local purposes and private protection; but, more recently, they have been planned with the intention to shut the water out from the swamps, on both sides of the river, for a great portion of seven hundred miles of its course; or, estimating both shores, for at least fourteen hundred miles of river coast.

In the progress of the levées no regard has been paid to those "bayous," or natural outlets, through which the Mississippi, in its unrestrained condition, vented, as it rose, a large portion of that surplus water, which, if these openings had not existed, would have been shed over the borders of the stream, and have raised the stratum of overflow still higher.

The numerous channels through which the rising floods were safely discharged into the swamps, with few exceptions, have been all stopped up by the extension of the levées across their mouths. Consequently, that portion of the flood which these openings allowed to pass into the great reservoirs of the delta, has been excluded from them, and is now forced, when the levées stand firm, to flow between the artificial banks down the main channel of the river.

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It will be readily perceived how this compression of that surplus water which, in the original condition of the stream, spread over a width of fifty or one hundred miles of inundated country, within a channel only half a mile in breadth, will cause the flood to rise higher and flow faster, until the additional volume discharged by the channel becomes equal to that which was before discharged by the bayous into the swamps.

The natural suggestion will, therefore, be, that, to relieve the river, we must restore its original condition by reopening these closed up outlets, and again allowing the water to pass out through its natural vents.

But this is now wholly impracticable. These bayous are all types of the Mississippi itself. They originally received their supply of water altogether from the river; and in extreme floods were subject, like the river, to overflow their borders. These overflows left a deposit, of narrow breadth, parallel with the channels of the bayous, and limited in the rear by the swamps. These narrow strips of elevated soil were arable, and offered attractions to industry second only to the beautiful borders of the parent stream; and they have consequently all been occupied, subdued, and are now often highly improved. The levées which have been thrown across the mouths of the bayous, now serve to protect the plantations on their ancient borders from the inroads of the Mississippi. To open them again would lead to the certain and immediate destruction of great interests, which have grown up along the outlets; and, at the same time, would prevent the possibility of reclaiming

the swamps themselves, which it has become an object of national and State legislation to redeem.

It will now be perceived why it is that the floods are constantly increasing in height on the lower Mississippi, and why it is so difficult to afford efficient protection to the country. The water which formerly escaped through these lateral vents, filling up the swamps slowly, or, as the flood increased, flowed over the borders of the great river and its tributaries, filling the reservoirs there provided still more rapidly, is now confined by artificial breastworks within the too contracted channel of the river. Consequently, as the levées are extended higher up, more water is excluded from the swamps, and the flood is therefore increased, and forced more rapidly, and in a deeper column, on the country below; thus compelling the lower planters to raise higher and make stronger the frail levées which originally sufficed for the protection of their isolated estates.

But these embankments have at length acquired such great breadth and height, in the southern parishes, that their secure maintenance has become exceedingly expensive, and their rupture the cause of great and frequent local disaster.

This is the leading cause to which the recent overflows of the Mississippi, along the coast of Louisiana, are attributable. It will presently be seen that the evil is rapidly increasing, and destined, if not speedily arrested by the strength of the nation, to devastate one of the fairest portions of this prosperous country.

The embankments which have been raised in past

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years to protect the borders of the stream from inundations, have been altogether the work of individual enterprise, carried on without system, under slight official control, and almost without concert. But it is not at all probable that the continuation of the work will hereafter depend on private means. Some of the parishes in upper Louisiana have already engaged in the effort to protect the coast, and State legislation will soon be invoked there as the only power adequate to contend with the increasing difficulty.

In the mean time the national legislature has taken the lead, and, by a general grant of all the inundated lands to the States in which they lie, for the express purpose of making "the necessary levées and drains to reclaim the swamp and overflowed lands," Congress has offered inducements to the States, and through the States to individual enterprise, to commence a vast system of drainage, with a view to the ultimate exclusion of the water of the Mississippi and its great tributaries from all the inundated lands upon their borders.*

It is not for one acting for the moment as an officer of the government, to criticize the past, or to dictate the future legislation of Congress; yet it may not be inappropriate to say, that, if the vast bonus granted for the purpose of excluding the water from the swamps above, and sending it down upon the States below, had been accompanied by an adequate appropriation to enable the States below to give vent to the water, or to pro-

* Act of Congress, approved September 28, 1850.

tect their borders from the deluge which it will bring, the good which was intended by the grant would have been accompanied by less destruction than is now certain, without additional legislation, to follow the donation.

As things now are, extensive works are in progress to exclude the water of the Mississippi from the swamps, and swell the floods of the river; while no step has yet been commenced to reduce those floods, or to guard the lower coasts from their consequences.

Legislation, in Missouri, has already responded to the Congressional grant, by an appropriation of $50,000 to begin the work of reclamation at the head of the delta, where many hundred square miles of inundated territory may be reclaimed by art, and the land subdued, drained, and brought speedily into tillage.

The legislature of Arkansas, with equal promptness, has passed an act granting to all proprietors who may construct front levées, the right to enter the donated lands where they may choose to select them, in payment for the cost of the levées which they may rear. The details of the act it is unnecessary to repeat; but it seems to offer the most ample guarantee for the ultimate levéeing in of the whole front of that State on the Mississippi, and the borders of the Arkansas River, from the high lands below Pine Bluff to Napoleon, on one side, and to the mouth of White River on the other.

The legislature of Mississippi, prior to the passage of the act of Congress ceding the swamp lands to the States for the purpose of encouraging their reclamation,

gave authority to the five northern coast counties of that State, to levy a tax of ten cents per acre on all the lands in each of those counties, for the purpose of constructing front levées, and shutting out the water of the Mississippi from the great swamps extending back to the Yazoo. Under the authority of this law, the county of Bolivar alone, since the last session of the legislature, has expended about $50,000 on the levées of that county—making therewith embankments which, combined with private levées, have closed up a continuous front of about thirty miles along the Mississippi.

The other counties extending down the coast, from the Yazoo Pass to the mouth of the Yazoo River, have been making similar, but less rapid, progress. The effects of these works will be noticed hereafter. It is merely necessary here to remark that they have already been most sensibly felt, although the line is still incomplete.

This action of the counties, under the authority of the State of Mississippi, it will be observed, *preceded* the Congressional donation of the swamp lands to the States for the purpose of stimulating such efforts. We have yet to witness the effect of that grant when the legislature of Mississippi shall have convened again, and followed up the example set by the States of Missouri and Arkansas, by additional legislation based upon the act of September, 1850.

Below Red River, the line of levées has been extended around Old River to the Atchafalaya, and is now in course of continuation down this, the greatest of the natural vents of the Mississippi; where all the

lateral bayous, or secondary outlets, for a space of thirty miles, have been recently closed up by the proprietors, and the water, always hitherto accustomed to pass through them, has consequently been excluded from several hundred square miles of swamp.

Without going into the minute details of this subject, it may be said that, by the inevitable progress of causes now at work, the Mississippi water is destined ultimately to be excluded from the whole of that vast area of the delta extending from the mouth of Red River to Cape Girardeau, as it has already been nearly excluded from the area between Red River and the Gulf of Mexico.

It is a curious problem now to determine what is to be the effect of all this. While population is taking possession of the plains of Missouri and the prairies of the Mississippi, there increasing the discharge of the streams, and forcing the floods forward, by opening new drains and removing obstructions from the natural channels; States, counties, and individual proprietors, further south, are projecting and executing schemes for the reclamation of the swamps, of which the direct tendency is to cut off all the natural outlets for the surplus water, and confine the volume now spread by these outlets over vast areas of territory, within the narrow channel of the Mississippi.

By viewing together the two great causes of increasing floods—the accelerated drainage of the surface-water from the cultivated plains, and the extension of the levées and systematic reclamation of the swamps along

the Mississippi and its tributaries—we must perceive, without the necessity of direct calculation, the inevitable fate of lower Louisiana, unless the progress of the hastening events be by some means arrested. The levées are being extended rapidly to the head of the delta on both sides of the Mississippi. They have been raised in low places along the American bottom above Saint Louis; they are found even on the smallest tributaries of the Ohio and the Mississippi; are rapidly stretching along the entire coast of the Arkansas; and have been attempted, and may yet be successfully introduced, on Red River.

The drainage of the swamps is progressing with a step as steady and as fatal. Without Congressional encouragement, the ingenuity and skill of every planter has long been directed to the extension of his estate by the reclamation of the adjacent inundated lands. But now a fresh impetus has been given to these efforts in the form of a magnificent donation to invite the States to undertake the work. The bounty offered must sooner or later insure the drainage of all the swamps of Missouri, Arkansas, and Mississippi. But the water that is excluded from them must sooner or later be poured down upon Louisiana. The swamps above will be redeemed; but, unless adequate preventives be immediately applied, many of the sugar-fields below will be replaced by swamps.

Let it not be supposed that these events, though all steadily progressing, are too remote to demand present concern. Those changes which may be witnessed by

persons now living, should be considered, for all the purposes of wise legislation, as things immediate. It is not assuming more than the actual progress of this country will justify, or more than is fully warranted by the history of the last thirty years, to conclude that at the close of the current century, or fifty years hence, the population within the present boundaries of this country will reach 100,000,000 of persons; and that of this number not less than fifty millions will be found within the region drained by the Mississippi and its tributaries. (See note F.)

Taking the area of this region at 1,226,600 square miles, its population in the course of half a century will average more than forty persons for each square mile. But a large portion of the territory lying between the western boundary of Missouri and the Rocky Mountains, will yield but a stinted reward to the labor of the farmer, and offer few incentives to stimulate to emigration. The richest tracts will be the most speedily and most densely peopled. The government will have been relieved of its surplus lands. The enterprising emigrant will no longer be able to purchase a farm of eighty acres of unsurpassed fertility for a hundred dollars, and must choose between the alternatives of a solitary home in the parched plains of the far West, or in the fertile but inundated lands of the delta.

It is our duty to look forward to these things. We see the work of redeeming these swamps advancing now; new levées being extended; new drains being opened; old outlets being shut off, and even the drain-

age-pump applied, in numerous places, to keep out the water. We now see an almost unbroken line of levées stretching along the coast from New Orleans nearly to the Arkansas, on the west side of the river, and above the mouth of White River on the east; and new ones rising, from point to point, almost to the mouth of the Ohio.

It is for reflecting citizens and wise statesmen to judge what, under these circumstances, is to be the immediate effect of State legislation and the national grant on the safety of Louisiana; or what may be the condition of things when a dense population, a scarcity of land, and the exclusion of the water of overflow, shall co-operate to give value to all the inundated region which may be reclaimed by labor, and pour the waters now retained in the swamps of the upper country upon the doomed parishes below. We must look at these things and appreciate the progress of society, and its probable effects, before attempting to devise plans to retard or resist the approaching event. The expedient that will be adequate to mitigate the present suffering will have no appreciable influence on the floods that are yet to come. That population will spread over the entire region drained by the Mississippi; and that the levées will be extended, in defiance of the natural difficulties and the probabilities of crevasses, until both shores are completely guarded, must be received as certain and inevitable results. That the water which is to be excluded from these reservoirs must be accommodated by the channel is also apparent. It is not merely the

present floods, therefore, but the effect of these progressing changes in the natural order of things, which it is our province to consider and our duty to provide for.

But, in pointing out the direct consequences of the system which now prevails to an extent so alarming—of excluding the water from its ancient reservoirs, and forcing the increased burden down the proper channel of the Mississippi—it is not the design to contend against that policy. It would, indeed, be a hopeless opposition that would array itself against the countless interests, private and public, which urge these measures forward. The progress of this work is irresistible. It has become the adopted policy of Congress, as well as of individual States, and is progressing fearfully through the whole area of the delta. It is impossible to restrain the States in their career of reclamation; and no hardship or discouragement can deter or daunt those resolute pioneers who are establishing their huts upon every dry patch where they can effect a clearing for a field, or sell a few cords of wood to a steamboat.

In fact, the interest of the whole country, as well as that of the States in which these inundations occur, does demand the speedy reclamation of the swamps. But the work can only be promptly accomplished by the construction of levées; while the levées which are thus constructed for the public good, and private benefit, are most unfortunately productive of extensive local distress. The process by which the country above is relieved, is that by which the country below is ruined.

The true difficulties of this problem will now be ap-

preciated. We can protect Louisiana, by simple means, from all ordinary natural floods. But the great problem with which we have to cope is, to ascertain how to protect her from the deluge created by the artificial improvements which are accelerating the drainage of the prairies, and diverting the collected waters from their natural course through the low lands.

It will thus be seen that it is the pursuit of individual and public interests, through all the northern States of the Mississippi valley, that pours the excess of water down. It may possibly be considered, therefore, that it is the common duty of the States to guard the land which these improvements now endanger.

It will be useful here to reduce some of these facts to figures, that we may have a more definite idea of the consequences that will result from the exclusion of the water from a given portion of the swamps, and confining the volume so excluded to the channel of the river, when the Mississippi has already overflowed its banks and is pressing upon the levées. It has been stated that the swamp lands of the delta are supposed to cover about 40,000 square miles. But if we confine our attention at present to that portion of this area which is found above the mouth of Red River, we may estimate its length, northwardly, at four hundred miles, and its average breadth at about sixty-five miles—dimensions which give for the total area of inundated lands, north of Red River, 26,000 square miles.

If we assume that the water over the whole of this area is excluded from the swamps to a sufficient extent

to reduce the depth of overflow only twelve inches, we shall have for the additional volume which, by that process, will be forced into the river, and which must, therefore, be carried off by the channel,

$$26{,}000 \times 5280^2 = 724{,}838{,}400{,}000 \text{ cubic feet.}$$

This additional volume must be discharged through the channel of the river in the ordinary period of high water—which, for the purpose of an example, we will here again assume to be sixty days.

The increased discharge through the channel due to this cause will then be 12,080,640,000 cubic feet per diem; and consequently

139,822 cubic feet per second.

This is about the *one-seventh* part of the actual high-water discharge of the Mississippi below Red River, as shown at page 42, and more than that portion of its total average discharge there at periods anterior to the erection of the existing levées.

But we have already seen that if only 35,000 cubic feet per second be added to the present high-water discharge of the river, its surface would be raised at or above Plaquemine, in the present condition of things, not less than twelve inches. It follows, then, that by reducing the depth of overflow throughout the swamps which are here supposed to be subject to inundation in high water, above Red River, only one foot, we shall raise the surface at high water below Red River nearly four feet for a period of sixty days.

In this calculation, it has been assumed that the depth of overflow prevented by the levées averages but twelve inches over the whole of the inundated area under consideration. But this immense area is really flooded, almost annually, to a much greater depth. We have no means of making any correct average on this head. In all parts of the swamps which have been visited by the writer, the depth is extremely irregular—varying from a few inches to more than twenty feet.

For the purpose of obtaining better data for an approximate estimate of the average depth of overflow, a cross-section of the delta was taken from the west bank of the Mississippi opposite Memphis, to the bluffs on the west bank of the St. Francis; the point, probably, where the opposite high lands approach most closely, in the whole region from the mouth of the Ohio to the Gulf of Mexico.

The results of this survey exhibited, for the actual distance from hill to hill, or minimum breadth of the delta, ...	35½ miles.
For the maximum depth of overflow, at high water, in the Black Fish Lake, . . .	42 feet.
For the depth at high water, in the St. Francis River,	52 "
For the average depth of the whole overflowed area,	$5\frac{17}{100}$ "
For the area of the section of overflow, . .	518,800 sq. feet.
For the breadth of overflow, from bluff to bluff, in a straight line, ...	19 miles.

From these results, it appears that at the point where the delta is probably the narrowest, and one of the points where the width of overflow is the least—if not the point where it is the least of all—the width of inundated low ground is nineteen miles, or thirty times as

great as the average width of the Mississippi; and the area of overflow *two and a half times* as great as that of the average high-water section of the Mississippi.

It is probable that *five feet* is about a fair average for the depth of the inundation, distributed over the total area north of Red River, which is subject to overflow.

Assuming this to be correct, and the area, which has never been surveyed, to be correctly stated at 26,000 square miles, it follows that, whenever the levées are made to stand firm and exclude all the water from the swamps, the quantity so excluded will be equal to five times that above obtained, or sufficient to require *an increase of discharge* through the channel, of

699,110 cubic feet per second,

kept up for a period of sixty consecutive days.

It has been shown that the actual discharge of the Mississippi in extreme high water, in 1851, below Red River, was 1,134,000 cubic feet per second. It follows, therefore, that to fill up the computed area of the swamps which are found above the mouth of Red River, to an average depth of five feet, will require a supply from the overflows of the river equal to 700,000 cubic feet per second for a period of sixty days, *or equal to the present total high-water discharge of the Mississippi for a period of thirty-seven days.*

In other words, if all the water which passes through the channel of the Mississippi below the mouth of Red River, when at its highest point, were discharged into the swamps above Red River, it would require a period

of about thirty-seven days to fill up all those swamps to an average depth of five feet. And therefore, on the other hand, if that portion of the Mississippi floods which is absorbed in filling up the swamps, were entirely excluded from the swamps, by a system of substantial levées, and forced into the channel—where an increase of 35,000 cubic feet per second will cause an increased elevation of surface of about one foot—the 700,000 cubic feet per second, so excluded, would raise the surface, by the formula, about fifteen feet above the present high-water marks.*

It will be observed that, to arrive at this approximation, it has been necessary to assume the two leading elements of the problem, viz., the area of the region subject to inundation, which cannot be correctly ascertained from any data in the land-offices; and the average depth of overflow, which has been estimated by mere local observation, and by inquiry of the best-informed persons whom the writer has encountered in the course of his investigations.

If these facts be not under-estimated, we may conclude that, to levée in the whole district, and reclaim all the inundated lands, will require levées of the usual height at the mouth of the Ohio, and gradually rising to about eighteen feet as they approach the mouth of Red River; unless, indeed, we are prepared to proceed

* Allowance is rudely made, in this computation, for the increased discharge of the Atchafalaya, the increased slope, and increased breadth of surface.

in the work upon the theoretical hypothesis, that the river will find means to enlarge its channel, in some appreciable proportion, as the volume which it is required to carry down is increased.

We shall defer the consideration of this theory for the present, and endeavor to trace the progress of that system which is now in vogue, and the continuation of which, it has been shown, is to be regarded as the certain consequence of the increase of population and progressive diminution of the amount of vacant land in the country.

The Mississippi River, from Cape Girardeau to Memphis, inclines towards the eastern side of its valley, and leaves the great body of its swamp lands on the west, where they are drained off by the River St. Francis and a network of bayous, having frequent connection with its channel.

Below Memphis, the river, bearing to the west, crosses its valley, and approaches the hills below the mouth of the St. Francis, leaving a great body of swamp land to the east, which there receives the waters of overflow, and drains them off through the channels of the Yazoo, the Sunflower, and some smaller bayous.

Below the mouth of the Arkansas, the river takes a nearly southerly course, through the middle of its valley, leaving the swamps of the Yazoo, some fifty miles wide, on the east, and those of Mason, Bartholomew, and Washita, of about equal width, on the west; so that, between the mouth of the Arkansas and the mouth

of the Yazoo, the swamp lands of the Mississippi—the great reservoirs of its waters of overflow—spread over a width of about one hundred miles.

Below the mouth of the Yazoo, the principal portion of the swamps is on the west, where they have a natural drainage through various bayous into the Washita and Black and Red Rivers.

Now, the flood that comes from the Missouri and upper Mississippi, first begins to overflow the banks of the river above the mouth of the Ohio, where a large volume of water flows through the pass between Cape Girardeau and the insulated high lands south of that place, and, spreading over a considerable area of swamp, discharges itself into the St. Francis. Below this insulated mass, the thin column of overflow is received into the lakes, bayous, and swamps of the southeastern counties of Missouri, lying between the St. Francis and the Mississippi; while the main channel of the river conveys the swelling wave further forward. The water continuing to rise in the river above, the column of overflow becomes deeper, and gradually extends along the whole front of Arkansas, above the mouth of the St. Francis, sweeping over all the lower portions of the western coast, and gradually filling up the great basin of swamps extending nearly from White River to the Mississippi, and supposed to cover an area of not less than 5,000 square miles.

Assuming that this area is an approximation to the truth, and that these swamps are overflowed at high water an average depth of five feet, this reservoir alone

must draw off, and hold in reserve, while the flood is passing through the channel,

$$5280^2 \times 5000 \times 5 = 696{,}960{,}000{,}000 \text{ cubic feet.}$$

But we have ascertained approximately, by actual measurement made when the water was within a few inches of its extreme height, that the whole discharge of the Mississippi River, above the mouth of the Ohio, during the flood of June, 1851, was 1,025,000 cubic feet per second, or 88,560,000,000 cubic feet per diem.

Consequently, the swamps on the western side, from Cape Girardeau to the mouth of the St. Francis, must draw off and hold back a volume of water, during a great flood, equal to the total discharge of the Mississippi itself, at Cape Girardeau, for a period of very nearly *eight days.*

The levée which the State of Missouri is about to build across the wide inlet below Cape Girardeau, will exclude the water of the Mississippi from a part of these swamps, and destroy them, as reservoirs, for that portion of the floods which they now absorb through this pass. But the further policy of the State of Missouri, as well as that of Arkansas, for the drainage of the residue of the inundated district above the mouth of the St. Francis, has not yet been fully developed. It is, however, certain that neither of these States can accomplish their object, or make the lands donated to them by the act of Congress extensively available, with their own resources, without constructing a line of levées along the whole front on the Mississippi, and excluding the water of overflow entirely. It may, therefore, be

assumed that they will be compelled ultimately to resolve on this course, if they have not already decided on its adoption.

We are not prepared to estimate what must be precisely the increased elevation of surface, to enable the river to discharge the additional volume which is now poured into any portion of the swamps, in a given period of time. But if we estimate the mass needed to raise the river twelve inches to be the same at the mouth of the St. Francis as it has been computed to be below Red River, from which it cannot very materially differ, we shall have for the increased daily discharge, which will be occasioned by an increased elevation of four feet—observing that there are 86,400 seconds in a day—

86,400 sec. × 35,000 cu. ft. × 4 = 12,096,000,000 cu. ft.:

From which we will deduce for the time required to vent through the channel of the river the volume which now passes, or is here supposed to pass, into the swamps above the mouth of the St. Francis, without increasing the floods more than four feet,

$$\frac{696,960,000,000}{12,096,000,000} = 58 \text{ days.}$$

We may conclude from this course of calculation, that, by constructing levées four feet higher than would be necessary to protect the borders of the Mississippi from overflow, in the present condition of things, at the mouth of the St. Francis, and gradually diminishing their height to that actually required by the present flood, as we proceed upwards towards Cape Girardeau,

we shall be able to exclude the Mississippi water, and drain all the swamps on the west side of the river, north of Helena. In this computation, however, it is assumed that the water is confined to the channel by levées on both sides of the river. If that be neglected, then the Kentucky and Tennessee low grounds will be inundated, back to the hills on the east, and levées of much more moderate height will suffice to protect the coasts of Missouri and Arkansas.

Now let us proceed to a lower point along the Mississippi, and ascertain the probable condition of things there. The water which will be shut out of the great basin now drained by the St. Francis, will be hurried down upon the State of Mississippi; first upon the coast which bounds the swamps of the Yazoo; and upon the opposite coast of Arkansas, from the mouth of the St. Francis to the mouth of the Arkansas River. But here again, as has been stated, works are in progress to ward off the waters and reclaim the inundated low lands. The northern counties on the west border of Mississippi have been for the last year, and are still, at work, raising embankments along their respective fronts to keep the river out. Extensive private levées on the opposite shore have been commenced below Helena; and the State of Arkansas is just embarking in a systematic scheme for the reclamation of her inundated territory. There is, in fact, ground enough to justify the assumption that an unbroken line of levées will be made, or attempted to be made, in the course of a very brief period, on both sides of the Mississippi River, at

least from the mouth of the St. Francis down to the mouth of the Arkansas.

If these levées be made competent to resist the weight of water, their effect, combined with the present levées on the Mississippi side below White River, will be to drain 5,000 to 6,000 square miles of swamps above the mouth of the Yazoo, and 2,000 or 3,000 square miles more, on the Arkansas side, between the towns of Helena and Napoleon.

All the water which will thus be excluded from an area here assumed to be 8,000 square miles—now supplied by the overflow conveyed through the Yazoo Pass,' and numerous bayous leading into the Sunflower and Yazoo Rivers—together with that excluded volume which will be sent down from Missouri and the upper portions of Arkansas, will be hurried on to the mouth of the Arkansas River, there to join the increased flood which the State levées, now in course of preparation on that river, are about to send forward to the same point.

It must be concluded, therefore, that the region embracing the mouth of the Arkansas, White River, and Lake Bolivar, is shortly to become the scene of extensive overflows, unless protected by the weakness of the works which are in preparation above.

It is important to take note of the condition of things here, for we may consider the mouth of the Arkansas River as in some degree the commencement of serious dangers, as it is in a great degree the commencement of most valuable improvements, which are threatened with destruction from the anticipated accumulations of water

at this point. It is a point which will also be found important in another aspect, viz.: as requiring a special examination with a view to ascertain whether it may not be practicable and advisable to leave a vent somewhere in this region, through the contemplated levées, for the purpose of eventually forming a great outlet to convey a portion of this artificial flood into Red River, and thence, by a corresponding outlet through the Atchafalaya, into the Gulf of Mexico.

The effect of all these contemplated works, from Missouri down, is obviously to concentrate the present waters of overflow, and hurry them on to the mouth of the Arkansas. But the plans which have been resolved on, and in a considerable degree executed, by the local authorities, leave no vent for them here. On the contrary, the counties of Mississippi from Lake Bolivar to the mouth of the Yazoo, as has been shown, have already nearly perfected, according to their own views of what is necessary, a line of embankment along their entire coast; while it has been seen that the commissioners of Arkansas are preparing to carry on the line upon the Arkansas side, until it meets that of Louisiana at the boundary of the two States.

If these immense lines of earth-work could really be depended on to control the Mississippi, and exclude the water from the swamps, we might perhaps be able to approximate roughly to the increased height of the floods which will be produced in the great river from the mouth of the Arkansas to the mouth of the Yazoo.

But a most important feature in the elements of this

problem, is the fact, that none of the States or counties have yet planned their levées with any reference to the increase of the floods which their own levées, or those in course of construction above or below them, will produce. In all cases they seem to be guided by the lines which mark the level of former high water.

This fact leads us to the discussion of two considerations that merit attention, in estimating the effect of completing the levées now in course of construction, which hold out a prospect of some relief; and, indeed, if properly improved, of certain protection, for a season, to the country below.

The most important of these considerations is the great difficulty that will be experienced in the first attempts to close up the works now in progress, so as to make the embankments continuous along the whole coast. Up to the present time this difficulty has not been so seriously felt, because the water has found vent through unlevéed districts above, and crevasses below. But each mile of levées that is reared and made secure, will increase the labor of constructing new ones and the cost of maintaining the old ones. Those that are now in course of construction, like all those that have been built in past years, are made with a view to resist the pressure of that depth of water which is anticipated on the basis of past experience. But past experience does not include the new elements—the effects which the levées will themselves produce on the height of the floods—and the first levées are, therefore, made too feeble, and will give way and be thrown back, and

rebuilt, perhaps many times—as the old ones have been—each successive levée rising higher and being made stronger than that which preceded it.

The water will thus be permitted to diffuse its force by spreading again over the swamps of the Tensas, the Yazoo, and the St. Francis.

This is a practical and certain guarantee for temporary reprieve to lower Louisiana. But it is, nevertheless, not one on which prudent men may permanently rely. Experience is acquired quickly in this country. The capital which will be invested in these new levées, however slightly they may be constructed, and the lands which will be reclaimed by them, however difficult to protect, will be additional pledges that the embankments will ultimately be made to resist the floods. Consequently, the difficulty of maintaining the levées above, though real, can only be regarded as in some degree an assurance that the whole effect of the works now in progress will not be immediately felt. But this is no substantial ground of hope for the future. The waters must ultimately be excluded from all the swamps, and pressed down upon Louisiana.

This State must, therefore, it is repeated, prepare either to give them additional vent, or to resist them, or consent to be deluged.

Moreover, it is to be recollected that while these frail works will fail of their present object, and be burst in numerous places by the floods which they will be the means of producing, they will, nevertheless, generally stand firm until the water rises nearly to their summit,

and when they give way, only fail in places of limited extent: so that, although the swamps will not at first be effectually drained, the water will be kept out of them, even by these inadequate levées, for a longer period; and the floods from the upper streams—which, by the wise ordination of Providence, usually send forward their spring waters after those of the lower tributaries have subsided—will be hastened on to meet those which come from the rivers below.

In short, the embankments which are now in course of construction in Arkansas and Mississippi will not be found sufficient to resist the higher waters which they will ultimately produce; but they will serve, nevertheless, to increase materially the height of the floods below, to hurry the wave forward, and thus add disastrously to the present distress of the people of Louisiana.

This State may look, therefore, for a temporary and partial reprieve, due to the insufficiency of the works which are in preparation to inundate her coast. And it is to be hoped that this precious time will be given to prompt and enlightened efforts to prepare for the approaching trouble; and that it will not then be supposed, if it should chance for a year or two that the flood of Red River passes off harmlessly before that of the Arkansas comes down, or that both of these have discharged before the Ohio pours out its volume—because there may happen for one or two seasons to be no coincidence of the freshets of the great tributaries—that the views here presented are mere speculations, or that the Mississippi is too great to be influenced by the labors of

men. They are, unfortunately, no speculations; and, if a year of low water should be permitted to intervene, it will be the part of wisdom for Louisiana to profit by the delay, and push forward her defensive works.

The other argument which has been urged as a ground of hope, is the probability that, as the depth and mass of water forced through the channel are increased, the size of the channel itself will be proportionally enlarged.

It is certain that this is one of the laws to which all streams flowing over alluvial beds are obedient; that, *cæteris paribus*, their abrasive force increases with the volume of water transported, and that the channel is enlarged as the abrasive power is augmented. But, before this can be made a ground of encouragement, it is to be observed that the scouring force of the river cannot be increased until *after* the surface has been raised; and, therefore, after the damage has been done.

This law is only available as an argument to prove that, though the people of to-day may be deluged, their descendants, if they continue the contest, and set back, rebuild, and strengthen their levées, will ultimately obtain relief. But *when* that relief will come—*when* the bottom will be washed out deep enough, and the banks will have caved in far enough to accommodate the increased volume, it is beyond the prescience of science, or the light of experience, to foreshow. Indeed, all our observations upon the Mississippi go to establish the presumption that, although the river, while depositing its bed, and forming its channel in the material which it transports, readily adapts its section to the volume which

it bears; yet, after that work is accomplished, its bed is formed and its dimensions are determined, it is extremely slow in its efforts to readjust its arrangements. The cut-off at Raccourci, made three years ago, is not yet washed out, by one-third, to the usual dimensions of the channel: though, by reason of the contraction of the water-way, the velocity of the current at that point is greatly accelerated. The Horseshoe cut-off was made many years ago; and up to this time the river at that place—notwithstanding the speed of the water is very much increased there in all stages of the river—presents a water-way of about twenty per cent. less than the average area of the river's section.

In fact, this principle of compensation, so often alluded to by scientific writers, offers no substantial ground of hope. It has value, perhaps, as a geological truth, but it affords no solid comfort to present society. When we increase the volume discharged by the river, the channel will no doubt undergo a gradual enlargement; but more than a thousand miles of material must be excavated and transported—re-deposited, re-excavated, and again transported many hundred times; and we have no reason to doubt that hundreds, and perhaps thousands of years will be required to do the work, and restore the ancient condition of things.

But it is contended by persons of intelligence and observation, that the construction of levées in the upper parts of the river cannot increase the floods essentially below; for the reason that the channel below is larger than that above, and can, therefore, vent between levées

all the water that can be brought down between any new levée which may be built above.

The assumption on which this expectation is founded is erroneous in fact. The Mississippi River may be, and is, generally larger near Red River than it is in the neighborhood of Memphis. Yet there are portions in its upper division, towards the Ohio, which are much larger than other portions below the Yazoo. And it may be added here, as a curious fact, in itself a perfect refutation of this view, on which hope has been promised, and a truth pregnant with other important consequences, that *the Mississippi, when in flood, discharges more water immediately below the mouth of the Ohio than it does at any point in the neighborhood of Red River.*

The maximum discharge of the channel below the mouth of Red River at the top of the flood of April, 1851, was per second . . .	1,134,500 cubic feet.
The discharge below the mouth of the Ohio, June 10, 1850, when the water was there *nine feet below the top of the flood of* 1849, was per second	1,223,000 " "
At the same point, at the top of the flood of 1849, by estimation, the discharge was not less per second than	1,700,000 cubic feet.

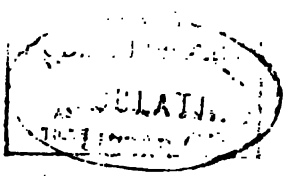
Apart from the inaccuracy of the facts, and the insufficiency of the elements upon which this view is based, it is at best a specious argument, and holds out but a fallacious hope.

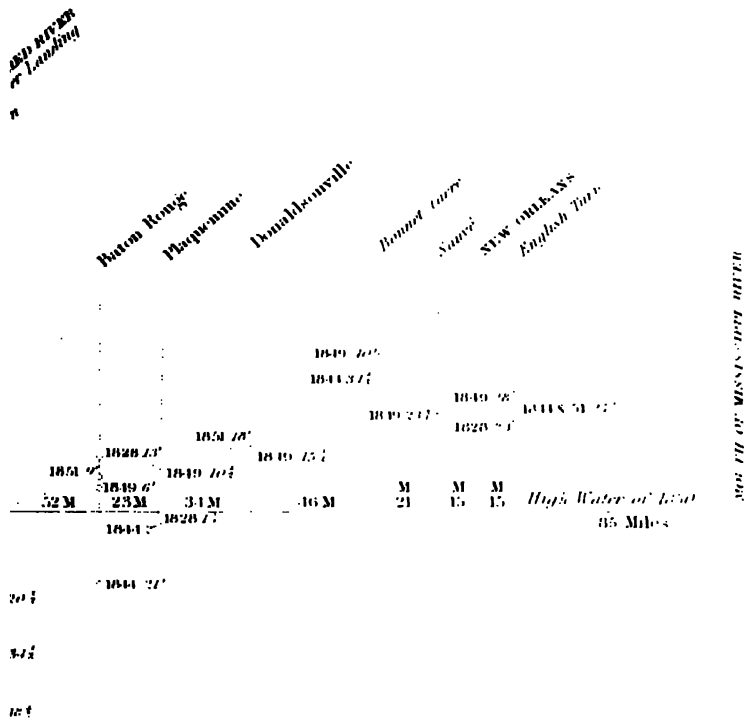
It in reality assumes that the water which is now discharged into the swamps above, passes through those swamps and reappears at their outlets, and aids

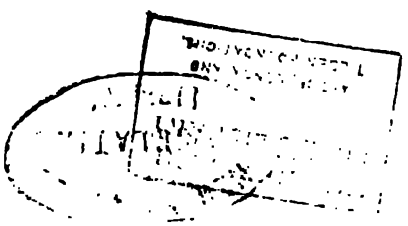
in swelling the flood in the river below. But this is all at war with the facts. The flood in the river travels faster than the flood in the swamps; and the highest rise at the mouth of the St. Francis is not produced by the water of overflow which entered those swamps above and is drained off by the St. Francis; nor that at the mouth of the Yazoo by the water which is drawn through the swamps of the Yazoo; nor that at the mouth of Red River by that which is discharged by the Cocodrie and the Tensas. The floods of the Mississippi are produced by water which does not go into the swamps at all, but which descends through the main channel of the river; aided by the discharge received from the tributaries on the way. The height of the flood at any point depends on the volume that is brought down by the river and its tributaries, and not by the discharge from the swamps. But, *after the river has attained its height*, the supply is kept up, and the duration of the flood prolonged, by the subsequent discharge from the swamps.

If, therefore, the levées be so raised at the mouth of the Arkansas, and the water so far excluded from the low grounds, as to produce an increase of the height of the floods there—say three feet—the height of the levées near the mouth of Red River must also be increased about three feet; the precise amount depending on local circumstances.

In fact, the effect of extending the levées, which is here contended for, was clearly demonstrated by the spring flood of 1851. As has been stated, the authorities




Red River
or Landing
Baton Rouge
Plaquemine
Donaldsonville
Bonnet Carre
Sauvé
NEW ORLEANS
English Turn
1849
1844
1849
1828
1850
1828
1849
1844
1828
1844
M
M
M
52 M
23 M
31 M
46 M
21
15
15
High Water at Low
85 Miles
MOUTH OF MISSISSIPPI RIVER



of the coast counties of Mississippi, during the previous autumn, had extended and closed up their detached levées over a continuous line of fifty or sixty miles—partly above and partly below the mouth of the Arkansas. But the levées were not materially extended on the opposite or Arkansas side. Consequently, the water was only excluded from the swamps of the Yazoo for this distance, and still had vent into those of Arkansas.

Now, the flood of 1851 was not a great flood. About fifty miles above the mouth of the Arkansas it was ten inches below the flood of 1850 in the Mississippi; and an equal distance beyond the back water from the Mississippi, the Arkansas itself, in 1851, was nearly *three feet lower* than it was in 1850.

The height of the flood of April, 1851, at the mouth of the Arkansas, ought, therefore, to have been expected to be at least one foot lower than it was in 1850. But in consequence of the levées constructed above, on the Mississippi side, by Bolivar County, the water was excluded from the swamps on that side immediately above the mouth of the Arkansas; and we accordingly find that the flood of 1851, at and below Napoleon, was within four inches as high as that of 1850. Here was a visible effect of eight inches due to the new levées above. (See Plate VIII.)

But the levées in Mississippi, as we have seen, between the dates of these two floods, were perfected many miles further down. Following the coast, then, about eighty miles, to the lower end of Bunche's Bend, we find that the flood of 1851 was *two and a half inches*

higher than that of 1850, instead of being, as it ought to have been, according to the volume sent down, about twelve inches lower. Here, then, was an effect of fourteen and a half inches apparently due to the new levées raised in Bolivar and Washington Counties, in the summer and fall of 1850.

Proceeding some ten miles lower, we find the flood of 1851 about *eight inches higher* than that of 1850, instead of being twelve inches lower; showing an effect of *twenty inches* near Lake Providence, produced by the new levées which had been formed above that place during the preceding season.

This effect was, however, of very brief duration. The levées were not prepared for this pressure, and gave way. A great crevasse occurred at Point Lookout, on the Louisiana side, below Providence, and numerous breaches had taken place on the Mississippi side, through which the water poured into the swamps of the Tensas and the Yazoo; and the flood below was accordingly reduced, and the levées saved.

Such results will be witnessed again and again. The country along the coast below will be saved by the feebleness of the works above. But each time the embankments break, they will be rebuilt and made higher and stronger; and each victory gained over the waters in the north, will consequently add to the distress of the south.

It is not to be supposed that Louisiana can afford to raise her levées as fast as the new levées above will make such a course necessary for her safety. The

levées near the head of the delta will be but five or six feet high, and be capable of sustaining a pressure of three or four feet of water. But if we add three or four feet to the height of a flood threatening an old levée, we must sacrifice the original bank altogether, and build a new one three or four feet higher. To resist a flood *increased four feet* in Louisiana, will require an expenditure more than three times as great as to build a levée adequate to resist a pressure of four feet in Missouri, besides involving the sacrifice of the old work. To maintain the new levée, apart from the increased risk, involves an outlay equally disproportionate.

It will be perceived that, in the view of the writer, the levées are destined to be extended the whole length of the delta, wherever there is inundated land to reclaim, of which the value, when redeemed, will justify the cost; and also that, as the water is excluded from the swamps and confined between the levées, it must continue to rise until it obtains depth and velocity sufficient for its discharge through the channel, or until the levées break; and that, practically, society can hope for no relief from the unassisted enlargement of the channel, or from anything but immediate efforts to give lateral vent to the water, or to restrain it by appropriate works. So long as the levées are raised and lengthened above, we must, therefore, expect the country below to be assailed by increasing floods.

In this state of affairs it is difficult to conceive of a case more deserving of the generous sympathy of the

country, than that of the people of Louisiana. It should never be forgotten that it is precisely those efforts which are resulting in prosperity and gain to their northern neighbors, that are pouring ruin upon them. It is not the place of the writer to point out what measure of protection justice demands for the injury inflicted by these works, or to say what, if the States of this Union were to be regarded in their reciprocal relations as individuals, would be the legal claims for redress of the one that is injured by a diversion of the waters from their natural course, upon the parties who, in the pursuit of their own interest, cause the injury. It is his study simply to point out the facts, and the physical remedies which may be applied, leaving the question upon whom the weight shall fall to repair the evil, to the wisdom of Congress.

PART III.

OF THE MEANS OF PREVENTING INUNDATIONS.

To persons unacquainted with the peculiar formation of the delta of the Mississippi, and especially to those who are unused to the measurement and contemplation of forces, the question of *absolute practicability* will naturally occur, when it is proposed to control and regulate the flow of a vast river, which is known to drain 785,000,000 acres, and discharge through its channel the floods produced by the melted snows of the Rocky Mountains and those of the Alleghany, together with the surplus water of hundreds of tributaries in the intervening valleys. It will be advisable, therefore, to glance at this question first, and attempt to compare the weight of water discharged by the river, with those ordinary powers which are directed by men.

If our object were only to relieve the country from the floods which are now felt, this problem, in the opinion of the writer, would involve no serious difficulty. Outlets could be made in lower Louisiana, and the levées could be strengthened along the coast, in the upper part of the State, to an extent sufficient to afford the most ample protection. But we have seen that

each year is destined to add to the power of the floods; that every mile of levée which is built increases the height and speed of the water; and that each new farm that is opened on the prairies, increases the volume that is poured into the streams. In short, it has been shown that the great difficulty of protecting the delta from overflow, is produced by the extension of the artificial embankments along the borders of the Mississippi, and the cultivation of the prairies of the upper States.

The real problem, therefore, is to decide how to guard against these artificial floods, which are annually increasing, by some counteracting artificial expedients.

It is not unreasonable to assume, that if it be in the power of individuals so to control the waters as to add to the height and violence of the river, it will be equally within the power of this government to reduce its force and moderate its velocity. Indeed, it might be shown, that force enough has been assembled in arms to protect the nations of Europe from the ambition of a single mind, to be able, if applied to such an object, to pump the Mississippi dry; that the standing armies of Europe are at this day sufficient, without the aid of science, and almost without the use of machinery, to *bail out* the floods of this river, and, pouring them into the sea through artificial conduits, maintain the water in the channel at any level that might be prescribed.

It is known, from measurements recorded in this paper, that the total discharge of the Mississippi and its natural outlets in extreme high water, is about

1,270,000 cubic feet per second; and that to raise the surface twelve inches, when at its extreme high-water mark, will require, in the average, an addition to its usual supply of about 35,000 cubic feet per second.

Now, the power of a horse is conventionally estimated to be equivalent to the raising of one cubic foot of water to a height of nine feet in each second of time; or, reciprocally, to lifting nine cubic feet of water to a height of one foot in each second.

The Mississippi and its tributaries are now navigated by about fifteen hundred steamboats, of which the average power may be safely estimated at four hundred horses. Consequently, the total horse-power engaged in transporting the products of industry through this valley—those products which it is the object of this investigation to protect from the effect of floods—is about equal to 600,000 horses. From which it follows, that the steam power actually engaged in navigating the Mississippi and its tributary streams, is adequate to the lifting of *all the water discharged by the river and its outlets*, at the moment when their discharge is greatest, as fast as it comes down, to a height of about

$$\frac{600000 \times 9}{1270000} = 4\tfrac{2}{10} \text{ feet.}$$

But, to reduce the surface of the Mississippi and its outlets below the mouth of Red River two feet, will only involve the discharge of about 75,000 cubic feet per second.

To lift 75,000 cubic feet per second to a height of two feet, will require a force of

$$\frac{75000 \times 2}{9} = 16{,}666 \text{ horses};$$

which is equivalent to the power of the engines of about forty-two steamboats of the average size of those engaged in the navigation of the western waters.

It is useful thus to compare the power of the river with those forces which men are accustomed to employ, for the purpose of showing that the quantities to be dealt with in controlling the Mississippi are not, as might be hastily assumed, too great for the means which it is in the power of this country to apply. Beyond this, such computations are of no practical value. They will serve only to show that, in order actually *to lift* the surplus water out of the channel of the Mississippi, and convey it through independent outlets to the sea, would not be too great an undertaking for this age; or, perhaps, greater than would be justified by the value of the vast area of overflowed lands which it is the object and interest of the whole country to reclaim.

It is, in fact, within the ability of society to restrain these floods by mere muscular strength—by steam-power—by a dead lift, and without the aid of any of those resources which are supplied by art and experience. But while it is useful, in contemplating subjects so large, to bring into comparison the things which are unknown, with others that we are capable, from daily experience, of readily appreciating, it is not necessary to pursue such a line of inquiry. We shall presently

find that great volumes of the Mississippi floods may be discharged directly into the sea, by merely removing a portion of the artificial embankments which now confine them to the river; or, that the floods may be controlled by retaining a portion of the water in the valleys above, until it may pass tranquilly to the ocean without injury to the country below. While we have the means of causing the river to regulate itself—to apply its own power to producing its own discharge—it would be unwise and unnecessary to seek extravagant modes of accomplishing our purpose.

It is proposed now to discuss these simple processes.

OF THE PLAN OF OUTLETS.

The mode almost universally recommended for obtaining relief from the overflows of the Mississippi, is that of creating artificial outlets to draw the surplus water from the river, and discharge it, through new channels, into the Gulf of Mexico. The earliest suggestion of this plan, which has been seen by the writer, is to be found in Darby's account of Louisiana, published in 1816, where its essential features, as they are at this day presented, are fully chalked out.

But, it is very certain that the preference almost universally given to this method is attributable mainly to the tempting facility of execution which it offers for the relief of the estates below Red River, and along the immediate borders of the Mississippi. The least knowledge of the physical formation of the lower portions of

the delta, is sufficient to satisfy every mind that this plan is perfectly feasible, and may be executed there with great promptness and efficiency. Indeed, along this portion of the river, the pressing difficulty is not to give vent to the surplus water, or send it to the sea by artificial channels; the precise difficulty is to prevent the flood from bursting through its artificial barriers and venting itself.

The Mississippi, as has been already shown, is actually elevated, during high water, from fifteen to twenty-five feet above the soil a few miles distant on either side of its course; and is only prevented from breaking out and deluging the interior by the artificial embankments which have been reared along its coasts. These embankments usually give way during high floods, in some weak points; and the *crevasses* thus formed act as vents to the overburdened channel. The proposition to create artificial outlets is here intended to supersede these spontaneous breaches; and for that purpose, and to that extent, they will be recommended in this paper, for the protection of lower Louisiana.

But this plan, simple, easy of execution, and certain as it is to effect the purpose, when applied to a limited extent on the lower portions of the river, is obnoxious to some well-founded objections, and has encountered much opposition from unfounded apprehensions.

First, among the legitimate objections, is the difficulty of giving vent to the surplus water which now comes down—and *à fortiori* to that larger mass which, in the view of the writer, is destined hereafter to come—in

sufficient volume to protect the coast without deluging other portions of the adjacent country, already suffering from the very excess that now prevails on the Mississippi itself. This is a solid objection to a plan in other respects highly useful and applicable, within reasonable limits. But it involves the necessity of sacrificing one interest for the protection of another which is assumed to be greater—an alternative which cannot fail to render it odious to all whose interests are threatened.

Another objection to this plan, which is also founded in reason, is the certainty that great deposits will be left in the lakes into which the waters withdrawn from the Mississippi will be discharged before they can reach the gulf; deposits which will not only impair the navigation of these lakes, but ultimately convert them into swamps, like those which it has become one of the great objects of the whole population of the delta to reclaim and bring under cultivation.

Then, there stands in the way the apprehensions, seriously entertained and forcibly expressed, by engineers of great intelligence and respectability, that the letting off a portion of the water by lateral channels will cause a diminution of the velocity of the current, and a consequent filling up and contraction of the present channel of the Mississippi below the points at which the water is withdrawn. Whence it is concluded that, as the channel of the river will become smaller than it now is below the new outlet, and the speed of the current will be diminished there, the discharge of that channel must become less in proportion as the

capacity of the outlet is made greater; and that, consequently, there will be really, in the end, no appreciable reduction of the height of the floods effected.

Finally, there is the opinion, thrown out and vigorously maintained by others, that these new outlets, having shorter routes and a greater descent than the river itself, will be rapidly abraded by the escaping water, and ultimately so much enlarged as to become the main outlets, or true channels of the river; and thus lead to the eventual destruction of the present channel and its invaluable navigation, and consequently involve the ultimate decay of the city of New Orleans.

As the plan of artificial vents, or *high-water wastes*, is here recommended as a prompt, efficient, and available means of relief for the coast below Red River, it will be proper to discuss these several objections at the outset.

EFFECT OF OUTLETS ON THE AREA OF THE CHANNEL.

The writer does not participate in the apprehension of those who look forward to a diminution of the present width, depth, or velocity of the Mississippi, from deposits consequent on the discharge of its waters of overflow through independent outlets. This apprehension is not at all shared; though the principle which looks for the accommodation of the size of a river's channel to the volume of water which passes through it, along a given slope, is fully admitted.

Certainly there are, in a channel formed in an alluvial

soil, reciprocal relations between the depth, breadth, slope, velocity, and discharge. In other words, these quantities are each functions of the others. But we are not thence hastily to conclude, that a certain portion of the high-water discharge of the Mississippi may not be withdrawn, without producing a proportional contraction or diminution of the breadth or depth of its channel. There are several impediments to this conclusion.

To excavate a channel through a soil of given texture, and to keep the same channel open when so excavated, are two distinct things, implying obviously very different applications of force.

To wash out a channel, requires a velocity and power not merely sufficient to carry off the material, but to overcome its cohesion and inertia, and transport it in addition. We find, consequently, that it is no easy thing, even with a great fall and a great volume, to open a new channel by the mere action of the running water of the Mississippi. The first attempts to make the cut-off at Raccourci, where the fall was at the rate of six feet per mile, or, more precisely, four and a half feet in three-fourths of a mile, were unsuccessful, although a considerable volume of water was let through an artificial trench leading from the river above to the river below the bend.

Various other attempts to create cut-offs at the bends in the upper portions of the river have likewise failed, although sometimes aided by a descent across the intervening neck, of seven or eight feet per mile.

The Atchafalaya and the Plaquemine have probably been open for ages—certainly from periods far beyond the reach of history or tradition—the first having a fall more than twice as great, and the other a fall *ten times as great* as the Mississippi itself; and yet, unaided by art, they have been found unequal to the task of increasing the depths of their channels, or enlarging their respective water-ways. On the contrary, the Atchafalaya, in the view of the writer, seems to have been contracting its original width for a great many years.

The crevasse at Bonnet Carré discharged into Lake Pontchartrain about the one-tenth part of the high-water burden of the Mississippi, for many consecutive days, during the great flood of 1850, when the water of overflow rushed down a plane descending fifteen feet in four and a half miles; and yet the velocity and force of the torrent were not sufficient to tear up the natural soil to any considerable extent. No channel was excavated. The furrows left by the plough and the roots of the crop remained on the field where it had been swept by the water, after the flood had subsided.

Without multiplying examples, it is admissible to say that the power required to excavate a new channel, or to enlarge an old one, is much greater than is needed to maintain such a channel after it is once opened.

It does not follow, therefore, that the capacity of the Mississippi will be diminished by high-water outlets, even if a part of the water which originally formed the channel should be withdrawn; for the reason that it

requires more force to create than is required to maintain the channel after its formation.

But there is another ground for the practical conclusion that extensive outlets may be opened without a shadow of fear for the preservation of the channel below. The Mississippi and its natural outlets are now greatly overburdened in times of extreme high water, and are unable to vent the volume which is poured into them by the distant tributaries as fast as it is brought down. This *excess* of water finds new outlets by overflowing the natural banks, or through crevasses in the artificial levées. Outlets, then, acting only as *high-water vents*, through which this surplus may be let off, cannot possibly diminish the actual area of the river's section below; for such outlets will discharge water which does not pass through the channel at all. The water which injures the country is not that which descends between the natural banks—or even that larger quantity which now descends between the levées of the Mississippi—but is precisely that which, after the levées have given way, leaves the river and spreads over the cultivated fields. We may surely discharge this portion through artificial openings leading to the sea, without affecting the area of the channel below; for it does not now, and never did, flow through the channel, and can have, therefore, no influence whatever on its condition.

Again: it has been seen that the volume discharged by the floods of the lower Mississippi is annually increasing, in consequence of the extension of the levées above.

In opening outlets below Red River sufficient to give passage to this *increased* supply, as it comes, we cannot possibly impair the efficiency of the present channel; for this increased discharge has had no part in the creation or maintenance of the present channel.

To the extent, then, in the first place, of discharging the waters of overflow, or the crevasse water; and to the further extent of providing for the increased discharge which the new levées will occasion, we may employ artificial outlets without the least apprehension that the present area of the river will be diminished by success. And still beyond this we may carry that expedient, until we approach the unknown limit which represents the difference between the volume needed to create, and that needed to maintain the channel.

These limits allow us margin to open outlets far beyond our means of producing, with proper regard to the safety of those upon whom the surplus withdrawn from the channel is to be turned.

A word may be added in allusion to the fear often expressed that the new outlets, which it is proposed to open at points where the route which the waters will follow to the sea will be shortened, may ultimately become so enlarged as to absorb the Mississippi itself, and thus leave the city of New Orleans on some secondary bayou.

The reply to this apprehension is the fact already stated, that the water passing through such vents is never known to cut out or deepen its channels without assistance. The bayous which still lead from the

river into the adjoining lakes and swamps, have been in activity during thousands of years, and do not seem to have gained the least on the Mississippi; while the whole delta shows evidence of ancient outlets which have been filled up by deposits, and now no longer act in relieving the discharge of the river.

The Bayou Plaquemine descends from its source to the Indian village, eight and a half miles, at an average rate of two and a quarter feet per mile, and in one place no less than three feet in a single mile, having a depth of more than thirty feet, and a current which can only be stemmed by a powerful steamer; and yet it does not appear to gain upon the soil or to enlarge its area. Indeed, the writer is not in possession of any fact which goes to show that any outlet can be made from the Mississippi, above New Orleans, which, left to itself, will become larger and ultimately excavate a new channel into the gulf. If we could calculate with confidence on such a result, the problem of protecting the country below Red River would be relieved of all its difficulties at once, for we might then open an outlet into Lake Borgne, and, turning the Mississippi into that arm of the gulf, transfer its embouchure to the deep water south of Ship Island, and thus promptly reduce its high-water surface some six feet at New Orleans. But, unfortunately, the water cannot open the way without assistance, and the new channel will not be produced without other aid.

The danger anticipated does not, therefore, exist. The channel will only be enlarged as we seek to enlarge

it; and it will of course be the duty and the care of the engineer to keep it always under control. For those, however, who apprehend that the tendency of things might be different, it may be said that these outlets can be completely controlled; that nothing is easier than to limit their discharge to the precise volume which we wish to pass through them. To *increase* their draft involves some difficulty. To stop them up entirely, requires no skill and but little labor.

The outlets which it is proposed to open, like the ancient natural outlets of the river, will only act in times of high water; and as the bottom of their channels will be eighty or ninety feet higher than the bottom of the Mississippi, and at the same time higher than the surface of the sea, to assume that they will be capable of cutting a trench to the gulf sixty or eighty miles distant, competent to drain the Mississippi, we must assume a power adequate to the excavation and transportation of that mass of material, or a prism eighty feet deep, three thousand feet wide, and sixty or eighty miles long.

There is nothing known in the past history of the Mississippi, and nothing that can be inferred from its present habits, to warrant such an assumption. The cut-offs, whether natural or artificial, to which so many former changes of the river's bed are referable, are not in opposition to this conclusion. To produce a cut-off, requires the excavation of a trench through a narrow neck of land, dividing one channel one hundred and

twenty feet deep, from another of equal depth, where the water is precipitated rapidly through the material to be removed, and conveys it directly into the gorge of the Mississippi itself, where there is a power always in activity to bear it away.

There is here the force to loosen the material, the space to discharge it into, and the power there to remove it as it comes. But, in the case of the new outlet, the material to be removed must be conveyed many miles through lakes and swamps, where the current is resisted by stagnant water, and the power of the river is necessarily exhausted; and it must finally be deposited in a shallow arm of the sea, which the transporting water has not the force to repel.

These objections to the use of outlets to a limited extent, are not tenable. It is, therefore, proposed to resort to high-water vents, so far as is necessary to obtain prompt though limited relief from pressing distress and impending calamity; but not to rely on this expedient exclusively, or even to look to it for full protection or permanent security.

The object of this examination is not considered to be merely the protection of the country below Red River from the difficulties against which the population there is now struggling; but to embrace the whole area of the delta, and to do the work by some plan that will not be incompatible with the intention of Congress, as it is manifested in recent legislation, to reclaim all the lands in that vast area which are subject to inundation. These great purposes will be aided, but not accom-

plished, by outlets; which, therefore, are now only recommended for local relief and limited application.

OUTLET BELOW NEW ORLEANS.

About eleven miles below the city of New Orleans, and one hundred above its mouth, the Mississippi approaches within five miles of the Gulf of Mexico. The ground between the river and the gulf, here known as Lake Borgne, is a plane sloping from the river back to the sea. The first three thousand feet from the river is cleared and highly cultivated land; but the residue of the distance is swamp, always wet, and sometimes completely overflowed by the high water of the gulf.

When the Mississippi is in flood, its surface stands six feet above the level of the adjacent soil, and the water is prevented from inundating the sugar-fields by artificial levées about six feet high.

At the distance of half a mile back from the levée, the surface of the ground is 9½ feet below the high-water surface of the river. At the distance of a mile, it is 10½ feet, and so continues, almost a perfect level from that point back to the borders of the lake, where the surface of the swamp or prairie is 10½ feet below the high water of the Mississippi, as it stood in the beginning of April, 1851.

The level of the gulf at the time of the survey was just 11 feet below high-water line in the Mississippi; but marks were exhibited which showed that, in 1848, the lake had risen to within seven feet of high water in

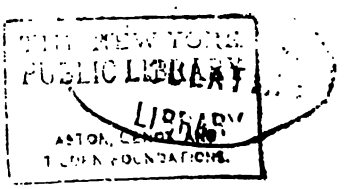

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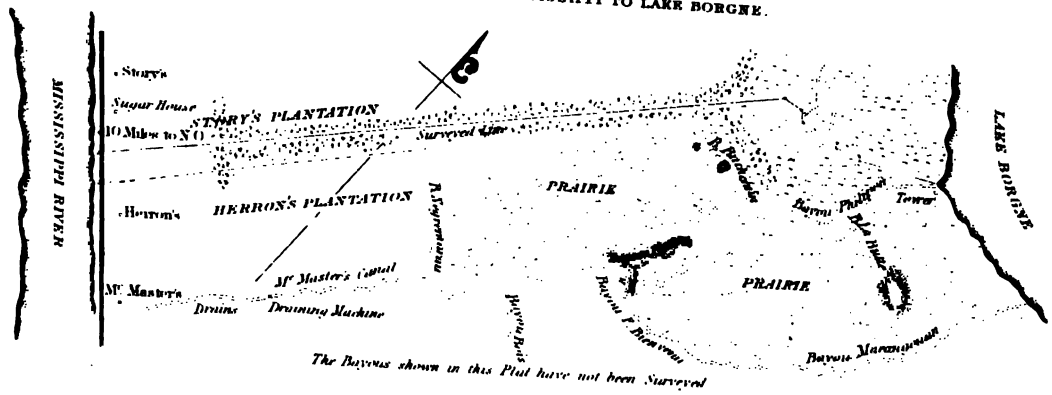
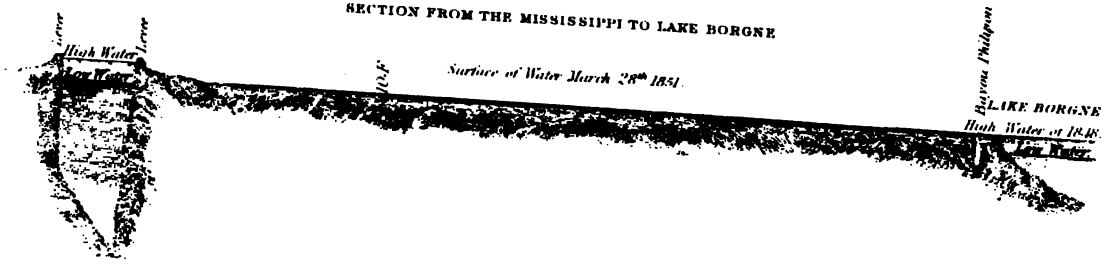
Plate 9

SURVEY FROM THE MISSISSIPPI TO LAKE BORGNE.



SECTION FROM THE MISSISSIPPI TO LAKE BORGNE



the Mississippi; and a low-water mark was pointed out which showed that the surface had at times receded to $13\frac{7}{10}$ feet below high water in the river. If we assume that the mean surface of the lake is eleven feet below high water, and the distance from the river to the lake in a right line, five miles, we shall have data near enough to the precise facts for all practical purposes.

The annexed section (Plate IX.), is a correct profile of the ground from the Mississippi to the gulf, showing the level of both as the water stood on the 7th day of April last.

It will be perceived from this profile and description, that if the levée that now confines the floods to the channel of the river were removed, the water would rush from the Mississippi towards the gulf in a column six feet deep. But, if the earth immediately back of the levée were excavated to the level of the swamp, or cut down $10\frac{1}{2}$ feet below the high-water surface of the river, the flood would pour through this opening in a column $10\frac{1}{2}$ feet deep.

The average fall of the surface, from the river back to the level of the gulf, before the water of the Mississippi had suffered any reduction (if the opening were made suddenly), would be $2\frac{1}{5}$ feet per mile. The velocity of the surface-current would therefore be, before this reduction would have place,

$$v = \tfrac{8}{10}(2.2\times10.5)^{\frac{1}{2}} + \frac{2.2\times10.5}{20} = 5 \text{ feet per second.}$$

If the levée were removed along a space of 5,000 lineal feet, the area of the outflowing column would be

52,500 square feet, and the discharge, consequently, about 210,000 cubic feet per second. But the actual discharge, while the length of the opening continued to be 5,000 feet, would be materially less than this amount; for the surface of the Mississippi would soon be depressed, and the depth and velocity of the column, of course, would be simultaneously reduced.

It is not at all probable, however, that the surface of the river could be reduced by this process more than 2½ or 3 feet, unless the torrent should be found to tear up the soil and cut a deeper outlet into the gulf. This is not likely to occur to any considerable extent, if the force of the stream be not aided by artificial appliances. But a deepening can be effected by cutting trenches from the river to the bayous which run through the swamps; clearing off the timber and loosening up the surface-soil; confining the water between lateral levées extending from the Mississippi to the gulf shore; and so placing movable obstructions in the outlet, that the water, in undermining them, might tear up the bottom.

It is the opinion of the writer that it will be practicable, for an outlay which will not be unreasonable, to form a vent at this point which will obtain an average depth nearly or quite equal to the difference between the high-water level of the river and the bottom of Lake Borgne near the shore, or about fourteen feet; and that such an outlet, thus increased in depth, will produce a reduction of the surface of the Mississippi at high water, of not less than four, and possibly five feet—an effect sufficient to secure the protection of New Orleans and

the whole coast below the city, and to some considerable distance above, for a very long period.

But it is not the purpose to recommend assigning any limit to the discharge that is to be poured through this outlet into Lake Borgne. It is proposed to cut boldly here; to encourage the action of the water by every effectual expedient, so as to reduce the surface of the river down as nearly as possible to the level of the gulf. All the water that is drawn off at this point, and all the reduction of surface that can be effected by this vent, will be productive of good. There is here no interest to be injured but that of the few individual proprietors whose estates will be appropriated, and to whom, of course, compensation must be made.

An apprehension is often expressed that the withdrawal of a large volume of water from any part of the channel will cause an increase of the bars at the mouths of the Mississippi, and therefore prove injurious to the navigation.

But it has been demonstrated by the writer, in a report to the War Department, which will be found in the Appendix to this paper, that these bars are not produced by the destruction of the velocity of the river, where the fresh water meets the sea, but by the refluent *under-current* which is set in motion by the outpouring floods of the Mississippi. It has, in fact, been shown that the bars at the embouchures of the passes, cannot be reduced in height by increasing the velocity of the river over them, and will not be increased in height by reducing the velocity. On the contrary, if the river

could be made to discharge a large portion of its burden by some other channel. the depth upon the bars would be increased by the action of the sea, which would then set higher up: and if the river could be turned off entirely. and let into Lake Borgne, the bars which are thrown out by the Mississippi, and maintained in the deep water of the gulf by its power, would be swept off by the waves. when a heavy sea would set into the mouth of the river. unresisted by the descending flood.

There is another point worthy of attention in discussing this subject. and which has been duly considered. The depth of Lake Borgne is very inconsiderable—varying from six to twelve or thirteen feet; and it would, therefore, if made the recipient of the mass of water which it is proposed to discharge into it, be soon filled up with the deposits from the fresh water of the river. This is an inevitable result, and the effect of the outlet, from this cause. would be gradually diminished. As the lake would fill up. the water discharged would flow through a channel of its own, between the natural levées which would be formed—as the banks of the Mississippi and those of all of its bayous have been formed—from the deposits left by the water flowing off laterally from the course of the outlet. This channel would gradually extend through the whole length of the lake, carrying with it a delta like that which characterizes the embouchure of the Mississippi, until it would ultimately, and indeed at no distant day, reach the deep water south and east of Ship Island.

It is the belief of the writer that it will be found

practicable, by dint of labor, and cutting boldly at the borders of the Mississippi, to make an outlet into Lake Borgne, which may be encouraged to increase until it eventually becomes one, if not the greatest, of the navigable passes to the gulf. This, indeed, should be the aim; and we should be encouraged to proceed with the plan, from the consideration that it is really the only great outlet that can be made from the Mississippi, that will be extensively beneficial to the city of New Orleans and the adjacent coast, and yet injure no existing interest; which we may work upon without cessation, doing some good all the time and endangering nothing. We shall presently see that those other outlets which it is the duty of the writer to propose, have not this important recommendation.

OF THE ENLARGEMENT OF THE PLAQUEMINE.

Next in value to the outlet which is recommended below New Orleans, in the estimation of the writer, will be found an enlargement of the area, and consequent increase of the present discharge, of the Bayou Plaquemine—one of those high-water vents left open in the original formation of the delta, and which have not yet been closed for local purposes.

It was a part of the natural adjustment of this great stream, to exhibit numerous openings through the elevated banks which form its coasts; where, in times of flood, as the water rose, it obtained exit by lateral channels which discharged into swamps, bays, or arms of

the gulf. These openings, fifty years ago, were very numerous, and were to be found on both sides of the Mississippi, from the mouth of Red River to the Belize. (See note G.) But in the progress of society, the population, which, allured by the productiveness of the sugar-lands, took possession of the banks of the Mississippi, closed up these outlets, by extending the levées across them; so that, out of forty or fifty, or more bayous, which formerly served to relieve the overcharged channel, there are now left but *three* which still act in high water for the depletion of the river. Of these three, it is here recommended to select the Bayou Plaquemine as the one most suitable, for divers reasons, to be increased in capacity, and made to replace a portion of those inactive outlets which have been destroyed by the levées.

The ruling motive for the preference here given to the Plaquemine, is the peculiar facility which its channel offers for prompt and economical enlargement. It has a more rapid fall than either of the other open bayous. It has a shorter route to the sea-level than that traversed by either of the other existing outlets. It passes through a district less highly improved than would be encountered on any of the other open or abandoned bayous. The volume of water which it discharges can, therefore, be more cheaply augmented than that discharged by any of the remaining natural vents.

The descent of the Plaquemine, from its source at the town of Plaquemine, on the Mississippi, to the Indian village, is, at high water, 19 feet.

The distance between the same points, by a survey

following the course of the stream, is 8½ miles. The descent in that distance is, therefore, at the average rate of 2.25 feet per mile; which is about ten times as great as the average slope of the Mississippi itself, in this part of its course.

This rapid descent of the Plaquemine renders the enlargement of its channel a work of singularly easy execution. The velocity of the current is now, in high water, from six to eight feet per second, and in places considerably greater. Its depth varies from twenty-five to forty feet.

To enlarge this channel, nothing is necessary to be done but to cut off two or three short bends, and then promote the attrition of the current against the salient points which it is proposed to remove.

The material which may be excavated should be taken from the north side of the bayou, where there are few improvements to be injured; and should be deposited in an ample levée, on the south side, so as to protect the country there from overflow.

The water may be forced to assail the banks, either by cutting them down perpendicularly, during low water, so that they may be undermined and fall in as the stream rises; or the object may be effected at high water, by anchoring stout barges against the points to be removed, provided with wheels to be turned by the stream, and armed with appropriate scrapers to cut away the soil as the wheels revolve and the current rushes by. The velocity is now, at surface, in some places, seven or eight miles an hour, and it can be

speedily increased to an average of seven miles by removing the projecting points, cutting off the short bends, and slightly increasing the depth across the bar at the source of the outlet.

By the exercise of ordinary prudence, there need be no apprehension that the water will scour out its own channel faster than is desirable. On the contrary, it will require vigor and skill to increase the discharge at this point fast enough for the relief of the coast. The work of enlargement will, however, be arrested by other considerations than any fear that may arise lest the Mississippi should turn its channel down the bayou, and find a permanent and principal passage, through Grand Lake, into the Atchafalaya bay.

It is not to be assumed that the water of the Mississippi can be discharged to any great extent through the Plaquemine into Grand Lake, without harm to other existing interests. There is, in fact, no point on the coast above New Orleans, at which a sufficient portion of the high-water burden of the river can be withdrawn to afford essential relief to the population there, without causing injury to some other community, and the destruction of some other interests.

The most that can be said, on this head, in favor of the Plaquemine over other outlets that might be proposed, is, that a greater interest will be relieved, and a smaller interest will probably be entitled to compensation for damage sustained, here than elsewhere.

It is this consideration, and none other, that will arrest the discharge which ought to be poured through

the Plaquemine into Grand River. But this consideration—the damage to property on the Teche, and other bayous tributary to Grand Lake, Berwick's Bay, and the Atchafalaya River—will be quite sufficient to compel us to arrest the discharge before the volume and speed of the current can lead to any serious apprehension of other dangers.

It will be observed that the water which is discharged by the Plaquemine is first received by Grand River, from which it is conveyed by numerous bayous into Lake Chicot and Grand Lake. These bayous find their way through great tracts of swamp, or inundated lands, into numerous shallow lakes, which are destined at no distant day to be themselves transformed, by the deposits which are left in them by the water of overflow, into similar swamps.

But it will be proposed, presently, to enlarge the Atchafalaya, another of the three existing outlets of the Mississippi, which also empties into Grand River, and through the bayous leading thence into Lake Chicot and Grand Lake. It will be seen, therefore, that Grand River is to become the recipient of all the waters of overflow which can be discharged by artificial or natural vents above New Orleans.

It is neither the intention nor the hope to obtain much more relief by means of an enlarged outlet at Plaquemine than that which is now rendered by the crevasses; but it is deemed advisable so to enlarge the capacity of this vent, that it may be relied on to dis-

charge at least as much water as now ordinarily finds its way to the swamps through breaches in the levées.

This will be effected when the capacity of the Plaquemine is made about four times as great as it now is, or when its present extreme high-water discharge is increased from about 30,000 cubic feet to about 120,000 cubic feet per second. It may, indeed, eventually become advisable to draw off a still greater volume at this point, if, after the amount of injury that may be anticipated by a given augmentation of the discharge has been accurately ascertained, it be deemed prudent to make remuneration for that injury, and push the enlargement of the outlet still further.

This, however, may be left for future consideration; after the first relief has been obtained, the immediate wants of the coast have been met, and the adjacent levées have been rendered secure; after the Atchafalaya has been enlarged as far as may be found expedient; and after experience, under the new order of things, shall have indicated the measure of further enlargement that would be proper.

There can, however, be no reasonable objection offered to increasing the draft through the Plaquemine until this bayou discharges into Grand Lake a column equal to that which is ordinarily received by that basin from the crevasses in the levées. And this is what it is here proposed to do: to increase the area and discharge of the Plaquemine until it can be regarded as a reliable substitute for those disastrous crevasses by which the channel of the river is now annually relieved. This

condition will exact a breadth at surface of 600 feet, and an average central depth of 40 feet, or that the area of the section of the Plaquemine be made very nearly equal to the present area of the Atchafalaya.

OF THE ENLARGEMENT OF THE ATCHAFALAYA.

The Atchafalaya is by far the largest of the existing or former outlets of the Mississippi; and it has been often proposed to resort to its channel as the best and most efficient drain for the floods which now threaten the country below its source.

In concurring with this popular idea, so far as to advise a commencement of the gradual and progressive enlargement of this great stream, it is not intended to represent the work as easy to accomplish, or in itself an effectual remedy for the floods of lower Louisiana.

It will, in fact, be found to be an exceedingly difficult and costly undertaking, and one which will need to be conducted cautiously and not too rapidly, if it is to be effected without serious injury to the region through which the water is to be conveyed.

The Atchafalaya leaves the old channel of the Mississippi about two miles below the mouth of Red River, and 310 miles, by the windings of the channel, above the Gulf of Mexico. It flows nearly in a southwardly direction; and when the Mississippi is swollen by floods, it serves as a natural vent for a portion of the present excess of water, of which it bears off a large volume to the sea. At its source, its average surface-

width in extreme high water is about 600 feet; its depth 55 feet; its slope six inches per mile, and its discharge not less than 85,000 cubic feet per second. It is about equal, measured by the area of its channel and the volume of water which it conveys, to *one-twelfth part* of the capacity of the Mississippi above New Orleans.

It has been long supposed that the Atchafalaya was the ancient bed of Red River, when that stream had no connection with the Mississippi, but found its way to the Gulf of Mexico by an independent channel. The union of the two streams—the Mississippi and Red River—is accounted for, in this theory, by the supposition that, at the point where their waters now mingle, their channels then exhibited opposing flexures, and the current gradually cutting away the intervening soil, brought the streams together and made their waters common.

This has become of late years a very popular theory, and is supported by several plausible arguments. The position of the mouth of Red River on the one hand, and that of the source of the Atchafalaya on the other; the direction by which Red River enters, and that by which the Atchafalaya leaves the old channel of the Mississippi, correspond perfectly with the assumption that the curves of the two adjacent streams gradually approached until they finally cut into each other. Besides, the color of the soil composing the west bank of the Atchafalaya at its source, indicates clearly a Red River origin. But, notwithstanding the plausibility

and force of these facts, they are not at all conclusive, but apply with equal directness to another view that will be here suggested.

In fact, the hypothesis which attributes the original formation of the Atchafalaya to the discharge of Red River, is found, on a careful examination, to be wholly untenable. It results from actual measurements of the channels of these two rivers, that while the Atchafalaya at its source has a prevailing depth at high water, in mid-channel way, of only about 55 feet, Red River, at its mouth, only three miles distant, exhibits a depth of more than 100 feet; that, while the Atchafalaya is confined within a channel less than 600 feet wide at its surface, in high water, the width of Red River, between banks, a mile above its mouth, is more than 1,100 feet; and that, while the descent of the Atchafalaya at or near its mouth is six inches per mile, that of Red River, where it enters Old River, is, at low water, less than one inch per mile. (See note H.)

The hypothesis of a former continuous channel, common to these two streams, so different in all their features, must, therefore, concede a sudden and remarkable change in the character of the supposed ancient Red River, at the precise point of the present junction of that stream with the Mississippi. Such a change, and the exact coincidence of that change with the point of accidental contact of the two shifting channels, is, indeed, not impossible; but it is, at least, quite improbable. A less violent and much more satisfactory theory, to account for the existence of the Atchafalaya

—one of the most remarkable features of the Mississippi —may be suggested, though the writer has not had full opportunities to submit it to a very rigid inspection.

Black River, the proper continuation of the Washita, corresponds much more closely in the dimensions of its channel with those of the Atchafalaya, than Red River. The general direction of the Washita is from north to south—corresponding well with the present general course of the Atchafalaya.

The idea has impressed itself upon the mind of the writer, that, in the original condition of the delta, the *Washita*, as well as Red River, descended by an independent channel to the gulf, which then, perhaps, set up through a bay as far as the head of Lake Chicot.

The Mississippi at that period pursued its present general direction. Red River had also its own independent channel to the gulf, in the present valley of the Teche, where it has left abundant traces of its course, in the composition of the soil, and in the width and form of the immediate valley of the present stream, from above the rapids at Alexandria down to Berwick's Bay. The Washita was thus an independent stream, descending to the sea between Red River and the Mississippi.

According to this hypothesis, the Washita and the Mississippi, by the gradual approach of opposite bends, ultimately united their waters, and the Washita was, so to speak, cut in two—the northern part afterwards serving as a feeder to the Mississippi, and the southern end acting as an outlet for its surplus water in times of flood.

The Washita having been a stream of smaller class than Red River, may be adduced as a reason why the present channel of the Atchafalaya, which was formed to accommodate the volume which that river, and not Red River, brought down, is insufficient for the discharge of the present volume of Red River. The Washita flowing directly down the plane of the delta, which it has been shown descends at the rate of eight inches per mile, accounts for the greater fall of the Atchafalaya, which takes the same direction parallel with the dip of the same plane.

Subsequently to the junction of the Washita and the Mississippi, Red River — then continuing on below Alexandria, in the same southeasterly direction which it still pursues above that point—flowed over its natural levée, and, taking an easterly direction through the swamps, united its waters with those of the Washita at the present mouth of Black River. Under this hypothesis, the increased volume below the confluence of these streams, in the course of thousands of years, may have produced the larger channel known as Red River, which even now is scarcely sufficient to accommodate their collected waters.

According to this view, which is suggested as the most plausible explanation of the existence of the Atchafalaya, that stream was the ancient channel of the Washita, or its prolongation, Black River; and the present channel of Red River, below the mouth of Black, was subsequently enlarged by the union of the waters of the Red and Black.

These considerations are not without a practical value in the present discussion. If it be true that the Washita had an ancient independent outlet through the Atchafalaya, the fact that this outlet has not increased in capacity since its function has been to give passage to the waters of the Mississippi, which it conveys to the sea-level by a slope twice as great as that of the Mississippi itself, is further evidence that the apprehension so often expressed, that it may ultimately absorb the Mississippi, is without reasonable foundation.

In fact, it is not yet demonstrated that this outlet may not have been one of those original vents which, like the Plaquemine, Manchac, and La Fourche, and numerous other bayous, were formed as the outlets near the mouth of the river are now formed, during the deposition of the soil, and for the purpose of relieving the channel of its high-water load. Be that as it may, the Atchafalaya has existed for ages, and now exhibits signs rather of a progressive contraction than an enlargement of its area. There is, in fact, not only no reason to believe that it will ever open its own channel wider and deeper, but scarcely even substantial ground to hope that this result can be materially promoted by any moderate amount of cost or labor.

The Atchafalaya, at its source, draws from the Mississippi, in very high floods, about 85,000 cubic feet of water per second, or about 8 per cent. of the actual discharge of the main channel of the river. But the right or west bank of the bayou, is overflowed in high floods by the back-water of the Mississippi, or by that of the

Red River; and below the mouth of the Bayou de Glaise, five miles from the source of the Atchafalaya, the extreme high-water discharge is consequently increased, by accessions from Red River, to about 140,000 cubic feet per second—or 13 per cent. of the total discharge of the main channel of the river.*

It is by observing these accessions from Red River, when the Mississippi has begun to fall, and the confined water of Red River obtains vent, that we are enabled to account for that red deposit on the west bank of the bayou, which has been so long regarded as conclusive evidence that this was once the proper channel of Red River itself. While the bayou is drawing in the water of the Mississippi at its source, the water of Red River, charged with its characteristic deposit, and deeply colored, flows rapidly through the swamps and pours over the whole west bank of the Atchafalaya for a space of four or five miles, from Old River down to Simmsport, and slowly mingles with that of the Mississippi. It is from this Red River overflow that the west bank of the Atchafalaya receives the red stain. But the overflow from that quarter diminishes as we descend, and the red deposit becomes also less and less clearly defined.

In this, the upper part of its course, the Atchafalaya

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* When the Atchafalaya was gauged (April 26, 1850), the water had fallen at its source 2.2 feet. The actual discharge was then found to be—

At its source	. . .	77,100 cubic feet per second.
Below Bayou de Glaise	.	122,700 " " " "

No observation was obtained at the time of extreme high water.

may be easily and cheaply enlarged. The purpose may be effected by first cultivating its borders and clearing off all vegetable growth, and then cutting down the salient points, and encouraging the action of the water upon them. The difficulty, however, of converting the stream into an efficient outlet is not found here at its source, but increases from mile to mile as it descends, until it discharges itself, by numerous mouths, into Grand River; and again, through numerous bayous, leading from that river into the lakes which intervene between it and the gulf.

The real difficulty consists in the fact, that the Atchafalaya loses its importance and its power as it advances below the Bayou de Glaise. It yields the water which it had drawn from the Mississippi and Red River, to numerous outlets, which diverge from it to the right and left; and, as it received accessions from Red River, which were discharged into it from the swamps above, so it discharges them again over its banks into the swamps of the interior below.

In passing down this stream in the latter part of April, 1851, when its surface had fallen 2.2 feet from its extreme high-water mark of that year, at Old River, and one foot at the head of Grand River, and gauging its volume from point to point, the following results were obtained:—

The Atchafalaya drew from the Mississippi, at its source, in Old River, per second, . . .	77,100 cubic feet.
It received accessions from Red River in the first five miles, which increased the discharge to, per second, ...	122,700 " "
At a point one mile above the Raft, the losses caused by lateral drains had reduced the discharge to, per second, ...	88,600 " "
At Picket's, one mile below Bayou Rouge and Bayou Latinache, its volume had been reduced down to, per second, ...	67,900 " "
At a point just below the source of Alabama Bayou, it was found to be only, per second, .	41,870 " "
Nine miles below the mouth of Bayou Little Devil, and half a mile below the re-entrance of Bayou Alabama, the discharge of this great stream had dwindled down to, per second, . . .	19,400 cubic feet.

In addition to the effect of these continual losses, by which its volume is reduced to less than the *sixth part* of that which its channel discharged at Simmsport, the power of the current in this outlet is still further reduced by a corresponding change in its rate of descent.

The actual descent in the lower part of the course of the stream was not measured, but the velocity was frequently tested; and, compared with the observations taken in the first twenty miles below Old River, they showed a falling off, in the speed of the current, of nearly one-half.

To make the main channel of the Atchafalaya capable of accommodating the volume of water which even now enters from above, the remaining obstructions at "The Raft" must first be removed, and the capacity of the stream must be increased an average of *fully three-*

fold its present value, for a distance of forty miles. If, therefore, it should be attempted, as has been suggested, to produce the enlargement by pouring in more water at the source of this outlet, in Old River, without first preparing the channels below to give it vent, we shall overflow a great extent of country, and retard for years, if not permanently, its proper and necessary drainage.

This is one of those cases in which every consideration of prudence and economy urges the commencement of the works of reclamation and enlargement *below*.

The Atchafalaya and the Plaquemine discharge their waters at the opposite extremities, and through various bayous, at intermediate points along the course of Grand River. This river is now, in fact, the recipient of all the water of overflow, and the crevasse-water, together with that of the natural outlets of the Mississippi and Red River, from the source of the Plaquemine to the Red River rapids. The water thus received by Grand River, from so many sources, is discharged from it, through numerous bayous and small lakes, into Lake Chicot and Grand Lake. These bayous are very crooked, and frequently obstructed. Their descent is small, and the current passing through them is, in many places, extremely sluggish.

If the enlargement of the Atchafalaya be undertaken, these bayous must be simultaneously relieved of obstructions to the passage of water through them, and straightened and enlarged; so that the additional volume of water received by Grand River may flow more readily into the lakes, and not spread over, and forever

destroy, the great area of swamps, yet reclaimable, by which these lakes are surrounded. The work of enlargement may then proceed upwards, along all the bayous which now drain the Atchafalaya, and which will still be required to vent the greatly increased volume that is to be conveyed.

It is not to be supposed that this work can be effected speedily, at trifling cost, or without involving much local damage. The accomplishment of the labor, so as to produce appreciable results, will require several years, however ample the means may be, or with whatever vigor the work be pressed; and a portion of the country will inevitably be flooded, however prudently its execution may proceed.

It was no part of the duty of the writer to investigate in detail the damages that may accrue from the accomplishment of this plan. It was sufficient to see and to know that the preservation of great interests from destruction will ultimately compel a resort to this measure. And as it is clearly in the power of those who control the progress of the work to arrest it, whenever the damage threatened is about to exceed the value of the results produced, it seems unnecessary to delay it for minute and doubtful estimates.

But, as already intimated, the enlargement of the Atchafalaya by any justifiable process, will prove to be a slow and expensive undertaking, involving great labor and loss of life. The work, therefore, though necessary and proper to be commenced, will not afford that prompt relief which is demanded by the present emergency.

The country needs immediate protection against actual distress, and effectual guarantees against approaching dangers. For these we must look to the Plaquemine as the only point, on the west side of the river, at which we can relieve the lower coast with the necessary dispatch. Another outlet will be presently suggested, in case of great emergency, as a temporary expedient; but the Plaquemine is, beyond all comparison, the channel by which we can most confidently undertake to produce visible and valuable results for moderate cost and with the necessary rapidity.

The Atchafalaya, when enlarged, will be much the most important outlet that can be obtained; because it draws off the water at the highest accessible point on the river. It is, therefore, not to be neglected; but is recommended here as a place at which the work should be commenced without delay. The superior merit of the Bayou Plaquemine consists simply in the fact, that, by its enlargement, the lower coast can be more expeditiously relieved than by any other possible outlet.

But let it be observed that neither the Plaquemine nor the Atchafalaya, nor both together, can be relied on to give vent to the volume of water which must be drawn from the channel of the Mississippi, when the lines of levées now in course of construction along the upper coasts are completed, and the floods increased, as they are destined to be increased, by the destruction of all the great natural reservoirs of the delta.

If we allow for the increased duty of the Atchafalaya, 150,000 cubic feet per second, we must assume that the

capacity of the channel of that bayou must be thrice as great as it is now. It is extremely doubtful whether the current can be made essentially to increase *the depth* of the channel; and if not, then the increased area must be obtained exclusively by an increase of the width; and the breadth of the surface of this great river must consequently become about sixteen hundred feet—or one thousand feet greater than it now is. This implies the excavation of a new channel one thousand feet wide and about fifty feet deep, and seventy or eighty miles long. If the water can be made to do the chief part of this labor, with the needful rapidity—which is the confident belief of others, and the doubting hope of the writer—it will be cheaper and better to resort to this plan, to obtain extensive and adequate security, than to any other which has yet been proposed. But, if this hope should be disappointed, and the labor of making the water act with proper efficiency in the lower part of the stream should prove much greater than is expected, or greater than can be endured, it may result that after completing the outlet into Lake Borgne, and enlarging the Plaquemine, and commencing a guard-levée of ample dimensions, *reservoirs* will then be the cheaper, as they will assuredly be the more certain, reliance for further protection.

We shall again recur to this question under another division of the subject.

OUTLET INTO LAKE PONTCHARTRAIN.

Next to the enlargement of the Plaquemine, by far the most efficient outlet that can be made, at reasonable cost and in a reasonable time, for the discharge of a portion of the surplus water of the Mississippi, will be a high-water opening leading from the concave bend at Bonnet Carré into Lake Pontchartrain. This expedient has been frequently proposed and elaborately discussed by others, but without the aid of previous instrumental examination.

The leading and true argument in favor of this plan is, unquestionably, the great rapidity and ease with which it can be accomplished. The prominent objections to it, in the view of the writer, are—

1. That the point where the outlet is proposed to be made, is too near the gulf to afford relief to any great extent of river coast.

2. That the deposits which will be discharged by the Mississippi into Lake Pontchartrain, will at first impair, and ultimately destroy the navigation of the lake, which must always be of great value to the commerce of New Orleans.

3. That the water withdrawn from the river will so raise the surface of the lake as to inundate the swamps on its coast, and in the rear of New Orleans; rendering it necessary to inclose the city on all sides within a levée, and rely altogether on the draining-pump to relieve it from the surface and sewerage water.

The distance from the Mississippi, at Bonnet Carré, to Lake Pontchartrain, is four and a half miles. The descent from the level of the high water of 1849, in the river, to the surface of the lake, at the date of the survey, was $16\frac{86}{100}$ feet. The fall per mile from the high-water surface of the river to that of the lake is, therefore, $3\frac{37}{100}$ feet.

The lake, when this level was taken, was considered to be about two feet above its usual low-water stage.

When the Mississippi is in full flood, its surface is about six feet above the natural bank at the proposed outlet at Bonnet Carré; and the natural bank, or immediate coast of the river, is here the highest part of the plane which slopes back from the edge of the river to the lake. The water of the Mississippi is, therefore, only prevented from pouring over its borders in a column six feet deep, and discharging itself at the level of tide-water in Lake Pontchartrain, by the line of embankment which the planters have raised for the purpose of protecting their fields from inundation. The floods of the river might be easily discharged in part at this point; where they would reach the level of the sea in 4½ miles, instead of following the windings of the river for a distance computed at 150 miles.

The profile shown in Plate II. will exhibit a correct section from the Mississippi to Lake Pontchartrain, at the point where the crevasse of 1850 occurred, and where a permanent outlet is so often proposed.

All that is necessary to be done to relieve the Missis-

sippi, at this point, of a portion of its surplus water, is to cut two trenches from the river to the lake, and use the material taken from them to form two parallel levées, at the distance of four thousand or five thousand feet asunder, and then remove the artificial embankments on the borders of the river, and let the Mississippi flow down the intervening plane into the lake.

In truth, nothing would be easier than to protect the country many miles above and below Bonnet Carré, or, in some degree, from the mouth of Red River to the sea, by opening a vent in the mode here described—for this opening may be encouraged to increase to any desirable extent.

Yet the objections already enumerated are so serious, that a resort to this measure, so simple and so certain to produce prompt but limited results, cannot be recommended here. At least, it cannot be recommended as a permanent improvement and a reliable plan, though it may ultimately be adopted, should events arise to justify it, as a temporary expedient. Should it be found, after the Plaquemine has been enlarged to the greatest admissible limit, and the outlet proposed below New Orleans has been effected, and the other plans which will be presently discussed have been carried to their utmost limit, that the section of the Atchafalaya cannot be increased fast enough to give proper vent to the increasing floods, then, and in that event only, will it be advisable, in the view of the writer, to tap the river at Bonnet Carré, and turn a portion of the remaining surplus water into Lake Pontchartrain.

The outlet proposed to be made by the enlargement of the Plaquemine, will draw off the water at a point seventy-five miles higher up the Mississippi than that at Bonnet Carré, and it will, therefore, afford relief to seventy-five miles more of the coast. The cost of the work will not be greater than the cost of that at Bonnet Carré, for we have the present channel, and the force of the water now running through the Plaquemine, to aid the undertaking.

The filling up of Grand Lake, and backing the water up the Teche, will be productive of less injury to property, and will impair a navigation of less value to Louisiana, than its admission into Lake Pontchartrain. The enlargement of the Plaquemine to the utmost admissible limit, should therefore precede the opening of any outlet at Bonnet Carré.

The absolute rate at which Lake Pontchartrain will be filled up by deposits, in case a portion of the increasing floods should be discharged into it, is not deemed of primary importance. It is enough for us to know that very great deposits will be made, and that they will not be left in regular strata over the whole bed of the lake, but in the form of *bars* and *islands*, which will speedily obstruct the navigation and render the channels always shifting and uncertain.

The quantities of earthy matter contained in the water of the Mississippi, in different conditions of its surface, have been investigated by several scientific gentlemen, whose results are not widely different. Preference is here given, however, to those published by Pro-

fessor Riddell, of New Orleans, who, to his scientific reputation and skill as a manipulator, has superadded the claim to confidence which is due to great zeal in this subject.

The experiments of Professor Riddell have led to the conclusion, that the proportion of sedimentary matter to the weight of Mississippi water containing it, is as follows:—

Water 1, maximum weight of sediment $\frac{1}{85}$.
Water 1, mean weight of sediment $\frac{1}{115}$.
Water 1, minimum weight of sediment $\frac{1}{215}$.

When solidified into coherent earth, at a mean, it was found that the *bulk* of the sediment was equal to the $\frac{1}{3000}$ part of that of the water in which it was suspended.

But the greatest amount of sediment is found when the river is in flood; and it is when in that condition that the discharge into the lake would take place. We may assume, therefore, from these experiments, that when there is a great flood in the river, the bulk of sediment would be to that of the water containing it, about as 1 to 1800.

We will assume, that if it should ever become advisable to draw off any portion of the surplus water of the Mississippi through Lake Pontchartrain, it will be necessary, in order to obtain any essential relief, to give vent to at least 100,000 cubic feet per second at that place. An outlet discharging less than this would produce but little impression upon the future floods.

There are 86,400 seconds in a day. The daily discharge of the outlet will then be

8,640,000,000 cubic feet.

Of this volume, $\frac{1}{1800}$ part will be coherent earth; or

$$\frac{8,640,000,000}{1800} = 4,800,000 \text{ cubic feet,}$$

of sedimentary matter will be deposited in the lake each day that the outlet is discharging at the rate of 100,000 cubic feet per second. If the annual discharge of the outlet average this amount for sixty days, the total deposit for the year will be

288,000,000 cubic feet.

Now, the average depth of Lake Pontchartrain is thought to be ten feet; and as a square mile contains 27,878,400 square feet, the annual deposit produced by this outlet would be sufficient to raise up an island one mile square and ten feet high, from the bottom to the surface of the lake.

These deposits would be irregular. In the course of a hundred years, there might be more than a hundred islands and shoals scattered over the lake, of which the height, and sometimes the position, would be changeable, and the channels, therefore, shallow and uncertain. Without entering into any minute computations, it is clear that an efficient outlet at Bonnet Carré is incom-

patible with the permanent maintenance of the navigation of Lake Pontchartrain. The ultimate loss of this navigation is, then, one of the sacrifices which must be encountered, when we resort to this unnecessary and apparently superfluous expedient.

The increased elevation of the surface of the lake which will be produced by this increased discharge, has already been alluded to.

Lake Pontchartrain is connected with the Gulf of Mexico by two narrow passes, known as the Rigolets and Chef Menteur. The tides of the gulf set up through these passes, and produce corresponding tides in the lake. The volume that is admitted into the lake by a high-water outlet from the Mississippi, must flow from the lake into the gulf through these passes; and, consequently, the surface of the lake must rise, until a sufficient *head* is obtained to produce a velocity through the passes, adequate for the discharge of the additional volume admitted.

Now, it has been shown by Professor Riddell, who has investigated one branch of this subject very beautifully, that, by the best data attainable without an actual survey of the passes, the elevation or head necessary to produce the velocity requisite for the discharge of one hundred thousand cubic feet per second, would be, by the formula of Wiesbach, but about one inch and a half.

But, admitting the fact, that if the two surfaces—that of the lake and that of the gulf—were permanent

and steady, as is assumed in the computation here referred to, this would be the whole effect due to the admission of that volume of water, we are not thence hastily to conclude that such will be the practical result. This problem is a much more complicated one, and requires for its solution a study of *the tides* of the gulf and those of the lake.

If the surface of the gulf were not affected by the tides nor by the winds, the elevation of the surface of Lake Pontchartrain, due to an outlet from the Mississippi discharging one hundred thousand cubic feet per second, would not, perhaps, be increased more than two inches. But the increased elevation due to this discharge is made much greater by the tides and winds. It is not intended here to say that the increased elevation of about two inches, which the assumed supply from the Mississippi would produce, is to be added to the elevation caused by the tides and winds, in order to obtain the total elevation. That is not the point. But it is the intention to say, that the tides and the winds greatly increase the elevation due to the discharge through the inlet—greatly increase the effect of a given volume admitted from the Mississippi. The problem here is not to compute the elevation of the lake, or the *head* that is necessary to produce a sufficient velocity in the passes to discharge the volume that it is proposed to introduce through the artificial inlet, but the *increased elevation* which is necessary to produce the *increased velocity over and above the tidal velocity*.

Thus, to reduce the surface of the lake twelve inches, there must be driven through the passes by the refluent tides, or by the winds, a volume of water equal to

$$530 \times 27,878,400 = 14,775,552,000 \text{ cubic feet.}^*$$

If this volume flow out of the lake through the passes in eight hours, we shall find, by dividing by 28,800 (the number of seconds in eight hours),

$$\frac{14,775,552,000}{28,800} = 513,000 \text{ cubic feet,}$$

for the volume which must be discharged through the passes in each second of time. Now, a variation of twelve inches in eight hours, in the height of the lake, is no unusual thing; and to give the velocity necessary to produce this discharge, Lake Pontchartrain must be elevated above the level of the gulf, according to the table of Professor Riddell, which is here adopted as a sufficient approximation, no less than $3\frac{25}{100}$ feet.

If, now, we superadd to the volume pouring through the passes under the action of tide and wind, a volume of 93,500 cubic feet per second, due to a crevasse or an outlet, we shall have, by the same table, a further increase of elevation amounting to sixteen inches. (See note I.)

In fact, a discharge of one hundred thousand cubic feet per second will affect the elevation of the high tides of the lake, by the best data that can be obtained without a thorough survey of the passes, not less than

* The area of Lake Pontchartrain, according to La Tourette's map, is about 530 square miles.

eighteen inches. And even this limit will be occasionally exceeded; as when a coincidence occurs between the maximum discharge from the artificial inlet into the lake, high tides in the gulf, and *floods in the natural feeders* of the lake—which are quite too important to be entirely overlooked.

It will be exceeded also for another reason. The water that will be received from the Mississippi will enter near the head of the lake; and to obtain a passage through the lake, it must communicate a certain velocity to the whole body of water contained therein. To produce this velocity will require a corresponding elevation of the surface at the head of the lake. In estimating this elevation, we cannot regard the entire section of the Pontchartrain as a mere conduit, having a given uniform velocity seaward. There will be an outward current passing somewhere through the lake, with eddies, or counter-currents, near its borders; and the elevation will be again materially increased from this cause. The writer hesitates, in anticipation of precise surveys, to assign a definite limit to the increased elevation of Lake Pontchartrain, which must be occasionally anticipated from the discharge of one hundred thousand cubic feet per second into it, by an outlet from the Mississippi at Bonnet Carré. But, from the best data now attainable—with all the details of which, and the calculations, he will not burden this volume—it cannot be set down at less than two feet.

In view, then, of the facts that such an outlet as is

here discussed must inevitably involve the destruction of the navigation of Lake Pontchartrain; ultimately convert it into a swamp; must greatly increase the ordinary height of its surface when the outlet is active; cause the entire shore to be levéed, and the cost of mechanical drainage to be greatly increased; without affording as effectual relief as can be obtained at Plaquemine without either of these sacrifices—the opinion is confidently expressed, that this expedient should be postponed until it is found to be absolutely indispensable. This necessity, there is every reason to believe, may never occur.

OUTLET AT THE MOUTH OF THE ARKANSAS.

Before dismissing the subject of outlets, it is proper to say, that although examinations have only been made with a view to the adoption of this remedy at and below the source of the Atchafalaya, it is by no means certain that the safety and the proper drainage of the country above may not compel a resort to this method, for the relief of the Mississippi near the mouth of the Arkansas, by a great conduit leading thence to Red River. If this should ever be done, it ought to be after the work of enlarging the Atchafalaya shall have progressed far enough to give a certain vent to the increased volume which this new outlet will bring into Old River.

This idea suggested itself with some force to the mind of the writer at a late period, and after becoming

satisfied that the mouth of the Arkansas is at no distant day to become the scene of a vast collection of water, which must either be discharged by an appropriate permanent vent, or through crevasses, whence it will inundate the estates on the Bartholomew, Mason, Tensas, and other streams between the Arkansas and Red Rivers. No investigation of this subject has, however, been attempted. To be made properly, special surveys, and a thorough reconnoisance of the parishes which the proposed outlet will traverse, will be needed.

OF THE OPENING OF THE BAYOU MANCHAC.

It has often been proposed to relieve the Mississippi by reopening the Bayou Manchac, one of those natural outlets which formerly drew off a small volume of water, and discharged it into Lake Maurepas by the channel of Amite River. It was not found to be necessary to make any extensive examination of this bayou, which was originally very insignificant, and is now entirely unfit for any useful application to the relief of the Mississippi. The source of the bayou, which was closed up to assist the military defences in the last war with Great Britain, by extending the levée across it, is only about six miles above Plaquemine, a point where, as has been shown, great relief can be obtained at little cost, and without serious damage to property. The water which would be drawn through the Manchac would be discharged into Lake Maurepas, and ultimately

into Lake Pontchartrain. The use of this channel involves, therefore, all the objections standing against an outlet at Bonnet Carré, and many others which do not appertain to that expedient. Indeed, the suggestion of an outlet at this place is entirely without practical value, and scarcely worthy of detailed discussion. The channel of the Manchac is long and narrow, and incapable of bearing a volume of water which could produce any appreciable effect on the floods of the Mississippi; and, if enlarged for that purpose, the cost of the work would be great, and the damage resulting from it excessive.

OF THE LA FOURCHE.

The Bayou La Fourche is by far the least important of the outlets which have been left open, and now act as vents for the surplus or flood-water of the Mississippi. This bayou gives passage, in extreme high water, to 10,200 cubic feet per second, or less than the one-hundredth part of the total high-water discharge of the river. Its descent near its source is only about 3½ inches per mile, which is but the one-eighth part of the average slope of the Plaquemine from the Mississippi to the Indian village. The velocity of the current is necessarily small, and it would not be practicable, therefore, to increase the capacity of the channel by the mere action of the water, if other considerations would justify the work.

But the extensive settlements on the banks of the La Fourche, offer a further and great impediment to the

enlargement of its channel. The work would involve excessive cost, if viewed only in reference to the physical difficulties; and a great outlay also in compensation for damages to private property.

An inspection of this stream shows that the same necessity for protection is felt along its highly cultivated borders, as has been experienced in so distressing a manner along the Mississippi itself. The bayou overflows its banks when the Mississippi is full, excepting as the water is confined by the artificial levées. But these levées have been very carelessly and slightly built; and are almost without exception of inadequate height and strength. When the Mississippi is in flood, the water along the bayou, for a great part of its course, stands within two or three inches of the level of the tops of the embankments. In many places, indeed, it is only retained within the levées by constant vigilance and labor. The embankments on which the planters here depend, are not as substantial as it is usual elsewhere to provide for a private mill-race; though the bayou is daily traversed by steamboats of five hundred or six hundred tons burden, which frequently push the water in a succession of waves over the levées into the adjacent fields.

The levées along the La Fourche are generally from ten to twenty inches wide on top; from three to five feet high, and of very irregular slope—each planter adopting that which his own judgment or fancy prescribes. When the water rises to the top of the levée, the proprietor commences driving pickets down into the

face of the bank, behind which a board is planted edgewise, and kept steady and in its place by a few shovelsfull of earth.

This frail bulwark, by constant attention, generally prevents the overflow; but when the river falls, these temporary fixtures tumble down, and are replaced again at the next high water.

To secure the property on this outlet from overflow in the present condition of things, requires a good guard-levée, not less than six feet wide at top, with slopes of three to one or more; and set so far back that there may be ample space between the new and old banks to be filled up with sediment, and thus strengthen the protection with age.

But it has been shown that the floods of the Mississippi are soon to be greatly increased, so that a much deeper column of water will enter the La Fourche at its source, and pass through it with a somewhat accelerated velocity. The present levées along the bayou are in very few places adequate to secure the plantations against the present floods, and they must disappear entirely before the wave that is to come.

It is recommended, therefore, to construct the guard-levées, which it is here proposed to build, at least three feet higher than those now relied on, from Donaldsonville down to Napoleon; at or near this place to open an outlet into Lake Verret, to carry off the surplus there, and discharge it into Grand Lake; and from Napoleonville to Thibodeaux, to bring the levée down to within a foot of its present height, by a gradual slope.

The fall from the top of the levée at Napoleon to Lake Verret, according to the survey of the State engineer in 1836, is twenty-two feet. The distance is seven miles and fifteen hundred yards. In the first mile and a half the fall is seventeen feet, or at the rate of 11⅓ feet per mile.

It would be extremely easy to create an outlet at this point of sufficient capacity to afford entire relief in high water to the whole country along the bayou. And, by cutting a canal from the lake up to a point within a mile of the La Fourche, and there constructing a lock, and an ample waste-weir, the same canal would serve to open a navigable steamboat passage from the Mississippi, by way of the La Fourche, to Lake Verret, and thence to Grand River, Grand Lake, and the Teche.

An effective outlet may also be made at Field's Mill, by cutting a new canal about one mile in length, or enlarging the old one leading into Field's Lake, and thence through the bayous from Lake Long to the gulf.

Either of these outlets will afford abundant protection against the present floods in the La Fourche, and greatly diminish the cost of the levées. But they cannot be made to produce any sensible effect on the height of the floods in the Mississippi.

The writer is aware that the construction of a guard-levée along the La Fourche, to resist the weight of the increased future floods, will be regarded as at least premature, and perhaps entirely superfluous. He makes the suggestion, however, after sufficient reflection, and

in the fullest confidence that these guard-levées will be found necessary—without assuming any increase in the aggregate volume of water discharged by the Mississippi —whenever the embankments along the coast of Point Coupée and West Baton Rouge are made high enough and strong enough to bear the weight which now presses upon them, without giving vent to the water through crevasses. If the water were entirely prevented from leaving the channel of the Mississippi above Donaldsonville, there are no levées now on the La Fourche that would not be at once overtopped by the present floods.

OF THE PREVENTION OF CUT-OFFS.

It has been shown that the consequence of cutting off the bends of the river, as has been effected on several occasions by design, and often, in the past history of the Mississippi, by the unassisted action of the current, is to increase the height of the floods below, and to reduce them above the bend. It is therefore recommended that prompt measures be taken to prohibit all attempts to effect or encourage such cut-offs in future, as well as to guard against their occurrence from accidental causes. Such a course will, indeed, afford no relief from present suffering, but it will serve to protect the river coast against one prominent cause to which we may look for an increase of future local inundations.

There are many points on the river where the water is gradually encroaching upon the soil, and reducing the width of the narrow necks of land which now separate

the channel above from that below the great bends of the river. It was not the province of the writer to engage in minute surveys of these places; but it was necessary to his investigation that he should ascertain whether the progress of the water upon the land at any of these points rendered immediate attention proper. With that view, levels were run across the narrow isthmuses, and other observations made, sufficient to enable him to judge of the probabilities of cut-offs having place at the several bends where they were thought to be most imminent. There were other bends which were not examined, though subsequently deemed equally worthy of careful survey. The points to which attention was particularly directed were—

1. The AMERICAN BEND, which commences about ninety miles below the mouth of the Arkansas.

This bend was examined May 15, 1851. The distance across the neck, measured to the water on each side, was 5,069 feet. The distance around the bend is computed to be fourteen or fifteen miles; but it was not measured. The fall of the water, or difference between the surfaces, as found by levelling from shore to shore across the bend, was 3.68 feet.

The evidence is conclusive, that the narrow neck in this bend is wearing away very rapidly. About twenty or twenty-five years ago, the distance across, which is now less than one mile, was fully three miles. It is thought by the resident proprietors that a width of four hundred yards, or more, has been cut away on the upper side in the last two years. The river is still obviously

encroaching upon the soil, and threatens to abrade it more rapidly hereafter, in consequence of a change in the form of the shore above, which causes the water to impinge more violently upon the bank at the narrowest part of the bend.

The land is cleared entirely across this narrow neck; and in high floods the current sweeps over it, and the water is consequently discharged over the loose bank into the reach below, with a pitch of about two feet.

A cut-off is very likely to have place in this bend at some early day, unless efficient measures be taken to arrest the progress of the current, which is now acting steadily upon the yielding soil. Should this be the result, there will be a local increase of eighteen or twenty inches in the height of the floods below the bend, at Worthington's Landing, and thence down to Princeton, and not a great deal less at Lake Providence. Indeed, the effect will be sensibly felt as far as Vicksburg; and it will be found impracticable to protect the coast in all that space—from the foot of the American Bend to Vicksburg—by the present levées. The consequences of a cut-off at this point will, in fact, be most disastrous. Some of the finest estates in upper Louisiana and in Mississippi will be inundated, or only preserved by the construction of an entirely new and costly line of embankment.

In view of the serious consequences which must result from a breach through this narrow neck, it is the duty of the writer to recommend that an accurate survey be promptly made of the entire bend, and of the bend

above, with the object so to change the course of the impinging current as to prevent the further progress of this abrasion, or to arrest it by works which shall be adequate to resist the river.

Provision should also be made by Congress to enter upon the undertaking as soon as these details are obtained, and the plan is decided on.

II. The TERRAPIN NECK BEND is at a point about thirty miles above Vicksburg. The distance across the bend was found by measurement to be only 1,580 feet. The distance around is variously estimated at from twelve to twenty miles. The fall, from the surface above to the surface below the bend, is 1.96 feet.

The river is constantly cutting this narrow neck away *on both sides*. It was not practicable, during the high water that prevailed at the time of the examination, to ascertain the character of the soil. But it was apparent that the caving now going on is very considerable on the upper side, for a space of more than two miles, and quite obvious also on the lower side.

A cut-off will be produced here, by the current itself, at an early day, even if the result should not be hastened by that portion of the public interested in its effects. But the river will not be permitted to work its own way. Last winter a ditch about fifteen feet wide, and three feet deep, was cut across the neck, into which the water was admitted during the flood. The current was strong, and the danger of an immediate cut-off was sufficient to attract the attention of the planters on the river below, who repaired to the spot

with their forces, and arrested the water by throwing leveés hastily across the ditch, and afterwards filling it up with trees and brushwood.

It would be charitable to suppose that the persons engaged in this work were ignorant of the mischief which it was likely to produce. It is scarcely to be assumed that any one who has witnessed the distress occasioned by the floods upon this river, would willingly inundate those beautiful plantations which are now only preserved by the slender protection afforded by the feeble barriers of the individual proprietors. This effort was probably prompted by ignorance; but ignorance may prompt it again, and there will be nothing to prevent a dozen misguided persons from inundating the whole coast for thirty miles above and forty or fifty miles below Vicksburg, by cutting a ditch here, which can be accomplished in a week.

It is important that this bend also should be promptly surveyed, and the most effectual measures taken to prevent the abrasion of the shores on both sides of the neck. It is not necessary, and it would scarcely be prudent, to make the survey one season and to do the work the next. *There should be no delay here.* The survey will occupy but a month or six weeks in the fall; and the work, which is not difficult, should proceed immediately after that has been accomplished.

If a cut-off be permitted to take place at this point, the whole coast on each side of the river will be swept, as Point Coupée has already been, from Milliken's Bend down to Grand Gulf. The effects will be less

obvious below, but the difficulty of maintaining the levées will be sensibly increased as far as Natchez.

III. The VICKSBURG BEND is the next point, in descending the river at which a cut-off seems likely to have place. The distance across the bend was found to be, from water to water, 7,712 feet. The distance around is estimated at ten miles. The fall, from the surface above to the surface below the bend, as the river stood at the time of the examination—about fifteen feet below the high water of 1850—was 2.25 feet.

Though the current here bears with great force against the bank on the upper side of the bend, it does not appear to be encroaching rapidly. Some work has been done on the neck, of which the object was represented to be to promote a cut-off; but it did not seem, as far as it had been carried out, that such was the actual purpose. Ditches have been commenced, but not extended entirely across the neck, and the timber that has been felled is left lying upon the ground.

A cut-off is not likely to occur here at any very early period, unless it be forced; and as one of the immediate effects of such an event would be to carry the navigable channel of the Mississippi several miles west of Vicksburg, leaving that town upon an inland lake, it is not at all likely to be accomplished by design, without meeting stern resistance from that place.

There does not appear to be any immediate danger of a cut-off at this point; yet such an event may occur in course of time, and it would, therefore, be wise to take measures at some early day to protect the shore

thoroughly, and to guard against the future chance by appropriate legislation.

IV. The PALMYRA BEND is a point at which a cut-off is much more likely to occur than at the bend opposite Vicksburg. The distance across the neck is now only 4,218 feet, while the distance around is said to be twenty miles; and the fall, as ascertained on the 7th May, when the water was eleven feet below the high water of 1850, from the surface above to the surface below the bend, is 3.64 feet.

If nothing were done to promote the invasion of the river upon the banks at this point, a cut-off would probably not occur here at any very early period. But the narrow isthmus that now separates the two channels bears indubitable marks of a fixed intention to produce this calamity.

A ditch was formerly cut across the neck, but it was not made large enough to effect the purpose, and shrubs consequently took root and sprung up before a sufficient flood occurred to wash it out deeper and wider. Another, but a very clumsy effort, was again made during the last winter, by cutting off the timber, clearing out a portion of the old ditch, and commencing a new one; but it is said that the parties engaged in this mischievous work were deterred, for the time, by threats from below, and consequently failed to carry out their intentions. It is apprehended that those who have undertaken this labor will not wait for the slow progress of the river, but may renew their efforts on some future and more favorable occasion.

It is earnestly recommended that this bend also be promptly and carefully surveyed, and such works commenced as will be found effectual in changing the direction, or resisting the action, of the current.

It is also respectfully suggested that the great interests likely to be swept by the perpetration of the plans of those who are engaged in this wicked project, would justify, and seem to call for, some appropriate legislation to guard the country against the wanton injury which is threatened.

If a cut-off should be made in this bend, the coast of Concordia, on the Louisiana side, and that of Claiborne, Jefferson, and Adams, in Mississippi, will be assailed by floods for which the present levées are wholly unequal. The mischief will be severely felt as far as Natchez; and the plantations thence to Red River will be deprived of much of the advantage which they acquired from the cut-off at Raccourci—an advantage that was gained by the sacrifice of many estates on the coasts in lower Louisiana.

The height of the floods will probably be increased by a cut-off at Palmyra Bend, ten or twelve inches at Natchez, and nearly twice as much at Grand Gulf.

V. The BEND NEAR GRAND GULF is the only other point at which instrumental examinations of probable cut-offs were made, though there is reason to believe that there are several others which will demand early attention.

The distance across this bend, when the measurements were made (May 5, 1851), was 3,907 feet. The

distance around is said to be seven miles. The fall, from the surface above to the surface below the bend, when the river was 9.5 feet below the high-water line of 1850, was 1.1 foot; and during the high water of 1851, as determined from the tree-marks, 1.3 foot.

The ground is gradually wearing away on both sides, and the distance across the neck is constantly, though slowly, diminishing. If the action of the river be not assisted by persons residing above, or others interested, there seems to be no immediate danger of a cut-off. But an effort has been made here, also, to assist the working of the river by clearing off the timber and cutting a very insufficient ditch. This effort may hereafter be repeated and more appropriate means adopted.

A cut-off at this point would increase the floods below from six to eight inches, and render the condition of many of the levées very precarious.

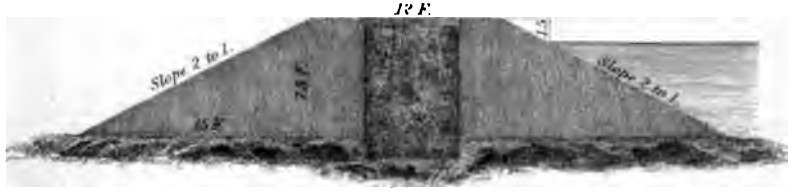
Cross-sections of the river were taken on both sides of each cut-off, which show that the Mississippi is making constant progress at every one of the bends here enumerated, and will ultimately cut its way through the intervening land, unless prevented by works adequate to change the direction of its current.

It is not, however, the intention to urge a permanent resistance to the working of the river. There are many reasons why these cut-offs should be permitted, and even aided, if it were not that the country below them would be deluged. In course of time, when the authorities in whom the control of the Mississippi is lawfully vested,

shall have adopted adequate plans for the protection of the delta and the reduction of the floods, and adequate means are appropriated to carry them out, and the work has so far progressed that an additional rise of two or three feet may be hazarded without apprehension, then, but not till then, it will be proper to cut off the great bends of the river, and let the water rise below them. But this thing ought not to be permitted before competent means are provided to protect the property below, or to compensate the sufferers below. Nothing can be more wrongful than to inundate whole parishes, by disturbing the natural adjustment of the stream, and leave a sparse community to contend unaided with the evils recklessly or ignorantly poured upon them.

It would seem to be expedient, in view of the great destruction of property which may be produced by cutting off the bends between Red River and the Arkansas, to provide for such attempts by Congressional legislation. This might be the means of at least preventing the acceleration of the evil. To prevent its occurrence from natural causes—by the slow and certain progress of the current—efficient works should be commenced forthwith, to protect the points assailed, by sheathing the shores, so that they will not wash away and cave in; or by changing the direction of the water, so that it may cease to wear away the soil at the points of danger, and, instead, deposit material that will serve as a protection.

SECTION OF CANAL BANK.



SECTION OF MISSISSIPPI LEVÉE.

OF PROTECTION BY LEVÉES.

The Mississippi River, it has been stated, is now confined and retained within its banks entirely by levées, extending along both shores for a space of nearly seven hundred miles of its course. These levées are private works, constructed and kept up almost altogether by the individual proprietors of the river front. The security of the country depends, therefore, on the vigilance, providence, good judgment and experience of perhaps five thousand, and possibly ten thousand individuals. There are statutes, it is true, providing for the repair of these works when thought to be insecure, and supervisors, whose duty it is to inspect the embankments and enforce a proper care.

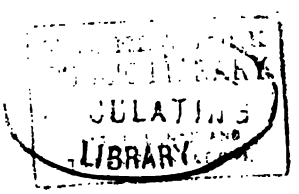
In case of the occurrence of a crevasse, or breach in the levée, the water rushes over the cultivated soil, and fills up the swamps, until it is ultimately drained off by outlets leading into lakes which communicate with the sea. The flow of the water is soon checked, on the up-stream side, by the gradual but general ascent of the country, which, it has been shown, dips from the north to south at the rate of eight inches per mile; and it is often arrested, in its course down stream, by the elevated borders of one of those ancient bayous which put out from the high banks of the Mississippi, as so many ribs from the vertebral column, and officiate as *traverses* in protecting the country from the advancing overflow.

To an engineer, accustomed to the dimensions of a

Plate 10.

SECTION OF CANAL BANK.

SECTION OF MISSISSIPPI LEVEE.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common canal bank, and the extreme care usually bestowed on its form and in its construction, it is a matter of some surprise to see what a slender bulwark men have ventured to place between the waters of the Mississippi and estates of which the fertility is a proverb. It is indeed wonderful to observe with what security the country trusts to the natural discipline under which this great river is expected to perform, each year, the precise movements of preceding years, and the surprise elicited by its occasional deviations. The levées have, accordingly, been raised but ten or twelve inches, or even less, above the known high-water marks, and are supposed, with such a margin, to be tolerably secure.

In the annexed sections will be seen, side by side, a specimen of a Mississippi levée and that of a common canal bank; each intended to resist a pressure of six feet of water. (See Plate X.)

The width of the canal bank, it will be observed, is three or four times as great at top as that of the levée; it has a much greater margin above the surface of the water, and it is built with a column of impervious *puddle*, to connect the bank with the best soil below. But, after taking all these precautions, and constructing the work with a degree of attention unknown on the Mississippi, the prudent engineer takes care to provide each level of his canal with adequate *wastes*, over which an accidental surcharge of water may be shed. Yet with all these safeguards, and the exercise of habitual vigilance, breaches are not unfrequent occurrences on the

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try above, and would be incompatible with the general drainage and reclamation of the delta.

But it is not the protection of the country bordering the Mississippi against the present floods, which constitutes the essential difficulty of this problem. It is simply to provide adequately for the increasing artificial floods about to come, by which we are embarrassed.

It has been shown that the work of reclamation in upper Louisiana, Mississippi, Arkansas, and Missouri, will and ought to continue to go forward; and hence the works of protection for the country below must keep even pace with these. For this purpose it has been recommended to open extensive outlets at various points, to give vent to this water as it comes; and to commence with the two—that leading into Lake Borgne and the enlargement of the Plaquemine—which can be most promptly brought into active and efficient service. The great outlet upon which we hope ultimately to place much reliance, the Atchafalaya, it has been shown, cannot be made serviceable in time to relieve the Mississippi of the threatening deluge. It will be recollected that we are to provide adequately for—

I. The floods which *now* injure and alarm the country. To make the coast below Red River tolerably secure against the present supply of water, we must keep the surface down at least twelve inches below its present high-water marks:

II. To effect this object, we must provide vents for the water that is now discharged through crevasses. To

dispose of this volume we must either rear levées, or make outlets, equal to the protection of the country against a probable rise of four feet above the present high-water mark. This condition alone, if we rely exclusively on levées, involves the entire reconstruction of all the embankments below Red River:

III. We must provide vents for, or protection against, the additional mass of water that is to be thrown into the channel as the cultivation of the new States above progresses:

IV. We must provide a vent for, or protection against, the greater volume of water to be poured down in a given time, in consequence of the extension of the levées and the exclusion of the floods from the natural reservoirs of the delta.

It is not the intention here, in dealing with such vast quantities, to seek, or to profess to attain great accuracy. But it is the belief of the writer, founded on the facts set forth in this paper, that to afford the needful protection we must provide means adequate to give vent to, or to resist, an increased discharge of at least 700,000 cubic feet per second, or about seven-tenths of the present high-water discharge through the channel of the Mississippi.

In this view he has set no limit to the volume that shall be drawn off by the outlet into Lake Borgne, but has recommended that the cut there be boldly made; and that the river be allowed to take the pitch of ten feet, and force its way through as deep and as wide a channel as its power can produce.

If it can make an entire new channel, navigable for ships, through Lake Borgne, and transfer its bars from the Belize to the deep water south of Ship Island, or produce a new one there, there let it go.

In this place, also, he has set no limit to the volume that shall be drawn off by the Plaquemine, but proposes that that outlet shall be enlarged until its enlargement be found to produce damage to the interior approximating to the advantage gained on the coast.

And in this view he proposes that the work on the Atchafalaya be commenced, though confident that the capacity of that bayou cannot be increased fast enough to meet the emergency of the case.

But in addition to all this, the protection of lower Louisiana will require other expedients. For this State, indeed, there is no alternative. She cannot wait for Congress to discuss, doubt, survey, and appropriate. She cannot wait for the slow machinery of legislation. She must build levées without hesitation or delay, or see her fields annually swept by the floods.

It is not intended here to recommend any given height of levée as sufficient in itself to protect fully any part of Louisiana. A line of guard-levées is proposed from Red River down to Plaquemine; and around Old River, and down the east bank of the Atchafalaya, as the means of affording the quickest protection against the floods as they are, or as they probably will be when this levée is capable of retaining the crevasse-water within the channel. But for those greater floods which are yet to come, this levée can only be regarded as an auxiliary protec-

tion, and a means of making the enlarged outlets do a greater duty. To perform this part, and retain within the channel the water now discharged by crevasses, without the aid of outlets, this guard-bank should be raised at least six feet above the highest known floods on the coast at the point where it is proposed to be built. It is indeed doubtful whether, from the best information that can now be procured, a levée six feet higher than known floods would have been more than sufficient to guard the country below Red River securely against the rise of February, 1850, if no crevasse had that year occurred for the relief of the Mississippi. The height of six feet is further proposed as a limit which it will be very difficult to exceed on the coasts above, and in the belief that, after such a levée has been completed, outlets and other guards can be prepared soon enough to meet the increased discharge as fast, or faster, than the works above can be made secure to send it down.

Simultaneously, therefore, with the enlargement of the Plaquemine, and the opening of a new pass below New Orleans into Lake Borgne, it is proposed to commence a line of guard-levées below Red River, thrown entirely back of all the present private or public levées, and to be raised in no place less than six feet above the highest floods. The present levées will serve in some degree to protect the strips of land lying between them and the guard-levée. The guard-levée will prevent the extension of overflows, and aid in reclaiming the swamps.

The cost of such a levée as is here proposed would be about $12,000 a mile. This will seem an extravagant

sum, and doubtless something cheaper will first be attempted. But to construct a proper levée on both sides of the river, from New Orleans to the mouth of Red River, and on the west side around Old River, and a similar appropriate work down the Atchafalaya to the Raft, will involve an outlay of at least $5,000,000. And in stating this, the writer wishes to express the further opinion, that if such a levée be now made it will not serve to protect the country below Red River, ten years hence, unless it be aided by those other expedients which have been, and which remain yet to be recommended.

It may be well to suggest that it might be good economy so to lay out these guard-levées that they may hereafter be used as the foundation of railway tracks, to accommodate that land now inundated, which a bold and sufficient course of improvement will speedily bring under tillage.

These suggestions are intended to meet the present state of things in Louisiana below Red River. This is the part of the delta which is first entitled to relief. If the work of reclamation and protection be commenced above Red River, either by Louisiana or by the United States government, the water there excluded from the swamps will be sent down to increase the existing distress, before the lower country is properly prepared to receive it.

If Congressional aid is to be extended to any portion of the delta, it is, beyond all question, clear that every consideration of justice, prudence, and humanity points to its first application to the country from Red River to

the sea. When efficient guard-levées and ample outlets are there commenced, and the means for their completion provided, then, and not sooner, it will be advisable and safe to extend the works higher up the coast.

OF THE PLAN OF RESERVOIRS.

We have now investigated the plan of outlets, and have approximated to the utmost effects that can be anticipated in attempting to dispose of the surplus water of the Mississippi by that device. It has been shown that there are great obstacles in the way of obtaining adequate relief by this process, and that the amount of relief which is possible will be limited by the destruction that may be produced in the districts upon which the diverted flood will be thrown.

We have seen that, as the next most feasible mode of obtaining prompt protection, we must resort to a more efficient system of levées in combination with outlets; but that, after costly levées have been built in the rear of the present banks, and all the water that can be reasonably discharged by outlets has been drawn off through appropriate vents, these expedients must still be regarded as mere palliatives, limited in their application to the lower part of the delta—and even there only warding off and postponing for a season, results which they cannot permanently prevent.

It has been shown, further, that the prominent causes to which the great floods of the Mississippi are attributable, are rapidly increasing in their effects, and will

continue to increase with the progress of population and improvement, and the increasing value of land; that these causes are to be found in the artificial drainage instituted by individual proprietors wherever the soil is turned by the plough, or overflowed land may be reclaimed by removing obstructions from the natural channels, and in the exclusion of the water from the vast reservoirs provided by nature throughout the length and breadth of the delta.

The conclusion to which the mind is brought by a comprehensive view of this great subject is, that, after exhausting all other means which art supplies, for relief, it will be necessary, in order to assure the protection of the whole delta from overflow, compatibly with the reclamation of the swamps, to construct new reservoirs in the hilly country, at the sources of the Mississippi and its tributaries; there to hold back a portion of the surplus water, and act as substitutes for those reservoirs which are thrown out of use in the lowlands by the innovations of society.

The vast importance of the subject must stand in justification of a further attempt—at the risk of some repetition—to explain the physical character of the delta, in reference to the applicability of this plan.

A great plane, bounded on the east and west by hills several hundred feet high, slopes down from a point above the mouth of the Ohio to the Gulf of Mexico, dipping towards the gulf at the rate of eight inches per mile. The Mississippi flows down this plane in a trench averaging 100 feet deep, and pursues a course

so serpentine as to increase the length of the stream to more than double the difference of latitude, and to reduce the slope of the surface to less than half the average slope of the plane.

At low water the surface of the river lies five or ten feet below the general level of the plane of the delta; at high water it attains a height of fifteen feet, and from that to twenty-five feet above the general level of this plane. As the river rises, it overflows its borders—which are elevated, by the deposit of previous overflows, nearly to the level of common high water—and, of course, inundates the adjacent low lands to the depth of fifteen or twenty feet in the places where the depression is greatest. The deposits from overflow are greatest on the immediate borders of the stream, where the first precipitation occurs; and diminish gradually as we proceed from the channel back to the swamps. A natural levée is thus formed by the material which is left on its borders by the stream when in flood. This levée is usually about thirty feet above the low-water surface of the river, and slopes off until it meets the low level of the swamps, five or six miles distant.

The tributaries of the Mississippi, and those of its outlets, are formed in the same manner and present the same features as those which characterize the Mississippi itself. In low water, they all lie below the general plane of the delta, and rise many feet above it when the river is high. They are all retained, excepting in times of great floods, between the levées which have been deposited by their own overflows.

The area lying between the Mississippi and the hills, and between the natural levees of the lateral streams, is in many parts inclosed by alternate "bluffs" and low ridges which, with the exception of narrow belts of higher soil, are all subject to inundation when the river is above its banks. In the lowest depressions are found numerous lakes and bayous, and sometimes important streams, which serve to drain this water of overflow into the Mississippi as the surface of the river falls.

It will thus be perceived that the primary function of a great portion of the delta lying between the narrow ridges of elevated soil which follow the windings of the streams, is to receive the water of overflow as the river rises, and thus mitigate the destructive effects of the flood. The whole of this region, with the exception of these elevated belts, found chiefly along the immediate coast of the streams, is therefore to be regarded as a *natural reservoir*, formed to receive and retain for a season the surplus drainage of the Mississippi valley.

Recognizing this fact, we are able to account for the *anomaly* which has already been noticed in describing this *great* river and its natural regimen. In passing from Memphis almost to the Gulf of Mexico, we find that the Mississippi maintains, with material local irregularities, about the same average width between its banks, and the same average area of water-way. It absorbs in succession the waters of the Ohio, the St. Francis, White River, and the Yazoo, and many other secondary streams, and yet appears to grow

no larger, and flow no faster; it takes in the Arkansas and Red River, each rising in the Rocky Mountains and flowing through a channel fifteen hundred, or, as many suppose, two thousand miles in length, and it is no more formidable after than it was before its column was swollen by these great contributions.

The reason of this is, that the water of the Mississippi is drawn off by bayous, as the flood descends, and is discharged into the lateral reservoirs of the delta. The water that is poured into the channel by the Ohio, is partly drawn out by the reservoirs along the St. Francis; that which returns again into the channel at the mouth of the St. Francis, is taken up again by the swamps of the Yazoo; and that which is discharged by the Arkansas, is scarcely sufficient to supply the reservoirs between the Mississippi and the Washita. The flood that comes from the Mississippi or Missouri parts with its water in passing from bayou to bayou, and is often entirely lost before it reaches Red River. *The swamps absorb it all.* A wave of fifteen or twenty feet at Memphis will scarcely be observable below Natchez, unless the rise continue for many days. The draft from the river into the reservoirs reduces the volume flowing down the channel in times of flood, below Red River, to less even than is found above the mouth of the Ohio.

Now, we have seen how the planters who have established their homes along the narrow strips of fertile soil forming the borders of the lower Mississippi and its tributaries, have, for years, contrived to protect their

estates from overflow by raising embankments near the edge of the streams, closing up the natural vents by which the water obtained access to these reservoirs, and confining it to its own proper channel. This water, unable to escape laterally, it is obvious, can only be discharged by rising higher and flowing faster. Thus it is that the portion of the floods which formerly filled the swamps for several months of almost every year, and then slowly drained off as the river fell—making a flood of more moderate height and greater duration—is now compressed between the levées, or artificial dams, and can only find vent by rising upon itself. Each mile that is thus added to the length of the levées above, leads to the necessity of increasing the height of the levées below, or, as an alternative, compels the planter to submit to a crevasse which shall sweep his own estate, and serve, in some measure, as a safety-valve for the protection of his more fortunate neighbors.

The effect of thus extending the levées has been fully discussed; and it has been shown that, by the plans adopted, this extension is ruinous to the districts already levéed, yet necessary to the immediate reclamation of the swamp lands, where the new levées are built, and, therefore, inevitable.

It will be readily admitted, that the question how to reconcile these great objects—of protecting the cultivated fields of the States below, while redeeming the swamps of the States above—involves some of the most formidable difficulties that can be encountered in the progress of useful improvement.

The physical difficulties alone are of the highest order, and, as we have seen, must be boldly and promptly met, or the lower and most beautiful portions of Louisiana must be abandoned. But it involves other questions of serious magnitude, and covers other vast interests. It brings up grave questions of individual rights, judicial control, and the rights of States. Viewing the immense stake at issue, or which, at no distant day, will be involved, it may be anticipated that if some adequate remedy be not provided, it is a question which will ultimately lead to serious conflicts of interest.

If it be a maxim of civil law that men shall so use their own as not to do injury to their neighbors, the right of the counties above to interrupt the flow of water through its natural channels, and force it down upon the parishes below; or the right of Arkansas or Mississippi to reclaim their swamps by converting the sugar estates of Louisiana into a swamp; or the right of Missouri to drain her lakes by overflowing the cotton-fields of Mississippi and Arkansas—are questions which may yet become as difficult to the jurist and the statesman as the control of this great river is now to the engineer.

The subjects involved in this problem are too vast in their consequences to permit men to evade their contemplation, or to shrink from the efforts necessary to obviate the approaching events, or to mitigate the impending results. Plans which, for ordinary purposes, it would be unsafe for a practical man to propose, and which, for ordinary purposes, it would be in vain to

suggest, for an object of this scope, may well command attention.

Now, it has been clearly shown that the prominent cause of increasing inundations, and that which is still threatening greater evils, is the exclusion of the water of overflow from the swamps, and the destruction of the natural reservoirs of the Mississippi, by means of those embankments, originally commenced near New Orleans, and gradually extended up the coast. As the swamps are thus prevented from officiating as reservoirs, the river itself is converted into an artificial reservoir. The water that cannot get into the swamps must remain in the channel until it can traverse its length; and the embankments must be increased in height until the river is capable of holding the flood, or until the column acquires speed enough and depth enough to effect its own discharge.

But the river is a reservoir of the most ineffectual character. To make it operative or reliable, either as a sufficient reservoir or conduit, more than 2,500 miles of continuous embankment must be reared and maintained on a caving and treacherous soil. More than one-half of this embankment has already been established, but not of sufficient dimensions to fulfil the purposes intended. The industry of individual proprietors, backed by the co-operation of counties, the liberality of States, and a vast donation by Congress, is now applied to the extension and completion of the line.

A bolder undertaking than that now contemplated has never engaged the thoughts, or been confronted by

the courage of any other people. It is even to be doubted whether it would be attempted here, with all the resources of the American character, and for all the inducements that stimulate the effort, if those now occupied with the work were fully aware of the magnitude of the labor, and of the future costs of reconstruction and maintenance which it will involve. No safe conclusion can be drawn of the influence which the closing up of these open lines of levée will have upon the floods, from any past visible results. The water, hitherto, has been but very imperfectly excluded from the swamps. It has found vent through wide spaces where there are yet no levées; through crevasses and abandoned lines. The present effort is to close up these gaps and make the banks continuous. But this, it will be found, can only be done after the old levées have been reconstructed on a broader base and raised higher.

The population—the sparse and by no means wealthy population—that has had the courage thus to face the Mississippi along its double front, and maintain their estates by damming the waters back, it is to be supposed will not be deterred from examining the project now suggested, of constructing dams upon the tributary streams which furnish this water, and substituting larger reservoirs in hilly districts, where the soil is valueless, for those which are destroyed in the rich bottoms of the delta. They who have already resisted the power of the river, where it has been necessary to construct dams along its whole course, on both shores, will assuredly be able to appreciate how much easier it will be to erect

proper dams across the gorges of a mountain, where the reservoirs are already formed, and bounded by high hills on every side, excepting the small gaps to be closed up.

It is not the intention now, however, to discuss the proposition which the writer ventures to suggest, in detail. That has been done in another paper, which has failed to win the general approbation of the public.* But it is his duty here to say again that it is entirely practicable, for a cost that will be fully justified by more than one of the great objects which will be accomplished by this plan, to hold in reservoirs surplus water enough to improve the navigation of every navigable stream in the Mississippi valley, by discharging the excess so retained into the channels when it is needed there; and at the same time, and by the same process, to protect the whole delta, and the borders of every river in it, primary or tributary, from overflow.

But the writer wishes not to be misunderstood; it is far from his intention to limit exertions to the plan which he deems essential to full and permanent success. That plan will relieve, not merely the country below Red River, but the whole valley of the Mississippi, from the site of the reservoirs in the distant mountains, to the gulf. It will ultimately reclaim the swamps of the entire delta, and convert the most worthless and least habitable soil into the richest and most productive.

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* See *Contributions to the Physical Geography of the United States*, &c., by Charles Ellet, Jr., published in the 2d vol. of the *Smithsonian Contributions to Knowledge*. This paper is added to the present volume as the proper continuation of the subject of overflows.

It will render every stream that is ever navigable, permanently so. It will remove that great difficulty which statesmen now find in deciding on what rivers are worthy of national care, by rendering them *all* national. For, surely, whatever helps to protect the whole delta, in any degree, from overflow, and at the same time improves the navigation of the Ohio and Mississippi, must be considered as of national importance—even though it may, incidentally, improve the navigation of the Alleghany and Illinois, so far as those streams are used as the conduits for the water.

Still, it is not the writer's intention to advise a dependence upon this plan alone, which has yet to pass through the slow ordeal of public investigation. On the contrary, he recommends a prompt and vigorous application of the power and resources of the proper authorities, whether national or local, to the preservation of the afflicted population of the delta, by all the means that have been discussed in this paper, and which may now be recapitulated.

I. The immediate organization of a proper system for the construction and maintenance of the levées of lower Louisiana, under the direct authority and control of the State: that a new or guard-line of levée be made —commencing at the mouth of Red River and extending down to the vicinity of Donaldsonville, above eighty miles above New Orleans, on both shores—of sufficient width at top for an ample roadway or railway track, and at least six feet above the highest flood which has

been witnessed at the points where the levée is to be built:

II. That, simultaneously with the commencement of these improved levées, there be formed a new outlet from the Mississippi into Lake Borgne, about ten miles below New Orleans, to relieve the river at that point and reduce its level there as nearly as possible to the level of the gulf:

III. That, without any delay, measures be adopted to promote the enlargement of the Bayou Plaquemine, so as to relieve the river, in that neighborhood, of the increasing pressure of the floods which will be produced when the water which now escapes through the crevasses is confined by the stronger levées recommended to be raised:

IV. That, simultaneously with the formation of these safety-valves below, and the construction of a guard-levée, the necessary steps be taken to encourage the enlargement of the Atchafalaya, by clearing off and cultivating its borders, straightening the channel, and undermining the salient angles of the shores which it is desirable to remove.

V. But, while recommending these prompt and vigorous measures, it is the duty of the writer to express his conviction that, after all these means of relief—carried as far as prudence and a proper regard to economy and the interests upon which this excess of water will be turned—have been exhausted, they will be found insufficient to secure even the State of Louisiana against the floods which, at no distant day, will

be poured down the Mississippi; while the great area subject to inundation, in the States of Arkansas and Mississippi, can receive no sensible relief from any of *these* expedients but that of levées. To secure the whole delta, it will be necessary to commence promptly and press vigorously the great work of retaining the water in the mountains.

We come then to the question which is to be decided by the enterprising men and reflecting minds destined hereafter to cope with this vast subject. Shall the upper States go on to construct their levées, and raise them higher and higher as the water is found to rise in consequence of their construction—endeavoring to overcome by levées the difficulties mainly produced by levées—doing work, daily, which will inevitably lead to the immediate necessity of more work to render that work secure—or shall they begin to adopt, in connection with that which produces so much incidental damage, a system of protection which, at every step, will do some good service to every interest? Shall it continue to be the policy—the favored and exclusive policy—to make whole provinces and counties depend for their salvation on the perfection of every part of several hundred miles of embankment; and to force every individual to seek to protect himself against the efforts of every interest above him? Shall this system continue until the artificial banks of the Mississippi shall vie in height with those of the Po, and the population in the low lands, behind the intrenchments, along a coast of more than a thousand miles, shall be in hourly

dread of crevasses of which the force will then be irresistible? In short, shall the aid of Congress continue to be invoked, and the legislation of States to be directed, to the indefinite prosecution of a scheme which adds to the present distress at every step of its progress, when the same results may be ultimately obtained by a process which harmonizes every interest and does good to all; which will, at the same time, protect the entire coasts of the Mississippi, and the banks of its tributaries; reclaim the swamps of the whole delta, and improve the navigation of every river of which the floods are received by the Mississippi?

But it may be asked, where is this work to be commenced, and how is it to be prosecuted, to accomplish visible results over a field so immense, in any reasonable time? The public mind has yet to be convinced that it is even practicable to retain a sufficient volume of water in the mountains to reduce the floods in the Mississippi any sensible amount. It has, it may be added, yet even to be persuaded to reflect upon the practicability of the suggestion. In the view of those accustomed to advocate and conduct difficult enterprises, it is precisely the persuasion and conviction of the public mind of the feasibility of a measure, that constitutes its difficulty. When men reflect on anything which has a solid basis of truth, they have arrived near the point of conviction.

It is not difficult to show that, to reduce the floods of the Mississippi one foot, we must draw off, or retain in reservoirs, about 20,000,000,000 cubic feet per week;

and that, to retain this volume, will require a reservoir 110 feet deep and covering seven square miles. Consequently, it would not be difficult to show, that, to reduce the floods twelve inches for a space of sixty days, would require that nine such reservoirs should be applied to that purpose. It would not be difficult to show that these reservoirs would retain water enough to maintain the navigation of as many of the most valuable rivers that flow into the Mississippi from the east; but, to bring the proof in detail, will require surveys; and to obtain such surveys, will require the confidence, leisure, and action of Congress.

But when the minds of men are directed to the fact that the floods are increased by the destruction of the natural reservoirs of the delta, it will not, perhaps, be difficult for them to appreciate that they may also be reduced by the creation of artificial and better reservoirs to replace those that are destroyed.

Under the operation of the causes which have been explained, the course of nature has been disturbed, and floods once regarded as exceptions to the usual order of things, are now of almost annual occurrence. Under the operation of human agency, and nothing else, the waters have been, and are still being diverted from their course, and concentrated in the great rivers; and it is now proposed to counteract the hurtful effects of this diversion, by works of art, calculated first to restore, and ultimately to improve, the natural regimen of the streams. It is proposed, in short, to construct new reservoirs to receive the increased drainage pro-

duced by the plough, and to compensate for those reservoirs which have been, and are about to be destroyed by the spade; to substitute for the swamps, which have always received the waters of overflow, capacious lakes in the rock-bound valleys of the Alleghany and Rocky Mountains. It would seem to be useless to demonstrate that such reservoirs will be cheaper and more efficient than the reservoir which has been formed of the river itself, by the levées, and which can only be made secure by the maintenance of from two to three thousand miles of embankment, reared on a soil always liable to slip and to be undermined by the action of the pent-up water.

In the view of the writer, every effort should be made, while new vents are being opened and guard-levées constructed below, to retain the surplus water in the lakes at the sources of the Mississippi and Missouri, and along the course of Red River; while proper sites for reservoirs should be sought in all the appropriate valleys of the Alleghany, and ultimately those of the Rocky Mountains. For this object, he has recommended that surveys be promptly instituted at the sources of the Monongahela, Alleghany, Kanawha, Cumberland, and Tennessee, and other tributaries of the Ohio, for the purpose of ascertaining the most advantageous sites for great reservoirs that will discharge through their respective channels. That, in the selection of these sites, regard be had primarily to the supplying of the Ohio and the greatest of its navigable tributaries with water in the summer months;—using

the reservoirs for the double purpose of withholding the flood-water from the Mississippi, when that river is overflowing its banks, and supplying the water so withheld, to the Ohio itself, and its navigable arms, when their navigation is impeded by droughts.

That these surveys be extended promptly to Red River and its tributaries, for the twofold purpose of applying the great lakes with which that valley abounds, to keeping back the floods from its suffering population, and relieving its summer navigation from obstruction, by allowing the surplus so retained to pass down in the season of low water. The lakes in the valley of Red River may be turned to good account in the prosecution of this plan; and the valleys of its tributary streams are understood to afford remarkable opportunities for the creation of great artificial reservoirs.

The flood of 1849, by the destruction of the cotton crop of Red River alone, was productive of damage to the amount of five or six millions of dollars, while less than half of this sum would probably have sufficed to create reservoirs sufficient for the permanent protection of all its valley, and the great relief of the Mississippi delta, from the mouth of Red River to the sea.

It is recommended that attention be first given to the control of the great navigable tributaries which pass through the most highly cultivated portions of the valley of the Mississippi; because on these a double service can be performed—the navigation can be improved while the floods are arrested. But, it is to be

recollected that while this motive prompts us to look to the distant arms, it is particularly those streams which, like the Washita and the Cumberland, discharge nearest to the point of suffering, that add most injuriously to the height of the floods of the Mississippi.

In closing his duties, the writer will venture to add a few suggestions touching the improvement of the navigation of the western rivers, which is necessarily embraced in this plan of restraining the floods. To produce useful effects, it is indispensable that the United States Government, or all the States in the valley of the Mississippi, enter at once upon a general system of river improvement. Snag-boats should be put at work upon the Mississippi, and all its navigable tributaries, in low water, to prepare their channels for the reception of a permanent supply. Reservoirs must be constructed wherever it is practicable to find appropriate sites—and the value of the existing commerce will justify the cost—large enough to receive and retain the flood-water of such tributaries, and let it off again when the supply is needed for the navigation.

It is not at all necessary to keep watch upon the reservoirs to see that they perform properly. It is perfectly practicable so to adjust their apertures that they may discharge constantly and almost uniformly; filling up when the flood comes down, and the supply is in excess, and falling again when the sources of supply begin to fail. The system, when fully carried out, will be almost self-regulating. While the snag-boats are at work preparing the channels of the great tributaries,

and the reservoirs are in progress of construction on the smaller sources, the outlets should be in process of preparation to the gulf, and the guard-levées should be advancing below Red River.

All these works will be necessary; and it is believed that by a general, prompt, and confident effort, directed simultaneously to the acceleration of the discharge of the waters below, and to their retention in reservoirs above, while strengthening the barriers on the lower coast, the works of protection may at least keep pace with the progress of those causes which threaten the ultimate destruction of the whole of lower Louisiana.

It is impressed upon the mind of the writer with the force of demonstration, that these several measures must be adopted, and adopted promptly, or that causes now in operation will speedily bring great distress throughout the delta of the Mississippi, from the mouth of the Ohio to the Gulf of Mexico. If they are adopted, this fertile country will prosper, and add vastly to the glory and wealth of the nation; if they are neglected, the population of the valley of the lower Mississippi must maintain a very long, though in the end, perhaps, a successful struggle against the increasing floods.

The position of Louisiana, in this eventful issue, is one of peculiar difficulty, and may result in inestimable distress, if she be left single-handed to struggle with the torrent which the industry and enterprise of the people of the upper States may pour down upon her devoted soil. However unequal and oppressive may be the contest, she can afford to lose no time, but must commence

at once, whether aided or alone, to protect herself by outlets near the gulf, and by the most efficient levées near Red River—levées, to prevent the deluge from sweeping over her surface, and outlets to vent the water more freely as it comes. Her fate is on this issue; and she is destined to bloom, the garden-spot of this great valley, if her skill, finances, and fortitude prevail, or to be known only as a desolate swamp if she falter and yield to the force of the flood. The question, whether she shall be allowed to stand alone, and protect herself unaided, from the difficulties forced upon her by the States above, or be sustained by that government which represents the power of all the States, is one of deep interest, which must be decided by the justice and humanity of the nation.

ON THE IMPROVEMENT

OF THE

NAVIGATION OF THE OHIO RIVER.

ON THE IMPROVEMENT

OF THE

NAVIGATION OF THE OHIO RIVER.

REMARKS ON THE PHYSICAL GEOGRAPHY OF THE MISSISSIPPI VALLEY.

THERE are few studies which exhibit beneficent design in a more impressive form than that which unfolds the adaptation of the physical structure of the earth to the wants of man. The mountains, planes, and valleys, the harmony of coloring, and all that appertains to the beauty of structure, speak to the eye, and require no aid from science to impress the imagination. The fertility of the soil supplies the necessaries of life, and calls for acknowledgment and praise. The stores of mineral wealth, formed for ages in advance, to be called forth in due season to aid in the support of industry, the developments of art, and the progress of civilization, are so essential to all the movements of the machinery of society, that the wisdom which ruled their formation, and prepared the treasure, could scarcely fail to inspire a tribute of admiration.

But the great features of the physical formation of the earth, the distribution of hills and mountain ranges, on which the clouds may break and condense into rain; the arrangement of the gentle planes that spread out from the base of each hill and mountain, until they intersect other planes which spread out from other hills and other mountains, and form channels at their intersection for the drainage of the surplus water shed from the adjacent slopes; the adaptation of these valleys by a happy combination of the dip towards the ocean, the area drained, and the development of the stream, to navigation and the wants of commerce, and the convenience of cultivated man—these are the studies of science, which require the aid of art and its improvements.

There are few divisions of the earth which offer more beautiful illustrations of this adaptation of natural means to an obvious purpose, than the physical geography of that portion of the United States which lies between the Great Lakes and the Gulf of Mexico, and extends from the Atlantic to the Rocky Mountains.

From the summit of these mountains a great plane slopes gently to the east, along which flow all the streams that enter the lower Mississippi and the Gulf of Mexico, from the west. Another plane, of nearly equal extent, and equally gentle in its inclination, descends from the north, along which flow the northern tributaries of the Ohio and the Mississippi itself, until it unites with the great Missouri, flowing along the irregular line which marks the intersection of these vast surfaces;

while another plane, descending from the summit of the Alleghany range, conveys the waters of the Cumberland and Tennessee, and all the southern tributaries of the Ohio, and intersects the great plane from the north, in the valley of the Ohio, and the greater plane from the west, in the valley of the lower Mississippi.

The intersection of the great slopes from the south and east with those from the north and west, near the confluence of the Mississippi, Missouri, and Ohio, creates what deserves to be regarded as a geographical centre of this remarkable region—a position which is rapidly becoming, from causes depending almost entirely upon its physical geography, the centre of commerce, wealth, and population of the whole North American Continent.

A single plane spreads from the summit of the Alleghany Mountains to the Atlantic coast, and turning the northern and southern flanks of that range, runs into the slope which sustains the southern tributaries of the Ohio.

The word *plane* is adopted here for the convenience of description only, and is not to be received in a literal sense. These great surfaces are furrowed by valleys, and relieved in places by hills and even mountains; yet these mountains are of inconsiderable extent compared with the vast area of the region described, and rest upon the great slopes which descend from the dividing ranges towards the Mississippi and Ohio.

The Alleghany Mountain is thus an elevated centre, from which the land descends and the waters flow in

all directions. Where it approaches the coast most nearly, in Pennsylvania and Virginia, the fall is rapid and the rivers of quick descent. They are therefore difficult of navigation; but as their development is short, they are less needed for that purpose.

On the reverse, or western side of this elevated range, the sources of the streams, and the land which their waters irrigate and fertilize, are far from the ocean, the great recipient of their commerce. And nature has here provided for the future necessities of an enterprising and improving race, by giving the streams which are to float the products of toil a greater space to glide over, a longer development, and a descent just sufficient to carry off the surplus water, with a current so gentle that it may be stemmed by the power which the genius of man is capable of calling into operation.

This law prevails throughout the globe. Those countries which are far from the ocean have long and gentle rivers, serving to drain off their surplus water, and to bear their surplus products. The sides of the mountains which front towards the ocean are abrupt and steep, their valleys are narrow and precipitous, and their surface rugged. While the opposite sides of the same mountains, looking into the interior, are comparatively gentle, and seamed with long valleys which form the tributaries of the navigable rivers that there commence their course to the distant ocean.

The Andes descends abruptly to the Pacific, which it reaches in a short distance, discharging from its sides small but rapid streams that run into falls and cata-

racts; while the long plane which slopes up slowly from the Atlantic, and forms the beds of the Amazon and La Plata, rises far on the sides of the mountain before the mountain itself becomes a distinct elevation.

It seems to be a rule in the natural economy, that countries remote from the ocean shall have outlets through great rivers of slow descent; rivers which serve primarily for their drainage, but so formed that they might be used, in the progress of time, for the highways of civilization. The planes of China are thus supplied with the Amour, and Russia with the Volga; Germany has the Danube, and Brazil and the States east of the Andes, the Amazon, Orinoco, and La Plata; all rivers of gentle descent, leading far into the interior, and all adjusted for navigation.

The Mississippi, Missouri, and Ohio, with their great arms, are the guerdon bestowed upon the central valley of the United States. The physical characteristics and capabilities of some of these it is here proposed to study.

OF THE OHIO.

In tracing the Ohio to its source, we must regard the Alleghany as its proper continuation.

This noble tributary rises on the borders of Lake Erie, at an average elevation of 1,300 feet above the surface of the sea, and nearly 700 above the level of the lake. The plane along which this river flows is connected with no mountain range at its northern extremity, but

continues its rise with great uniformity, from the mouth of the Ohio to the brim of the basin which incloses Lake Erie. The sources of the tributary streams are generally diminutive ponds, distributed along the edge of the basin of Lake Erie, but far above its surface, and so slightly separated from it, that they may all be drained with little labor down the steep slopes into that inland sea.

From these remote sources, a boat may start with sufficient water, within seven miles of Lake Erie, in sight, sometimes, of the sails which whiten the approach to the harbor of Buffalo, and float securely down the Connewango, or Cassadaga, to the Alleghany, down the Alleghany to the Ohio, and thence uninterruptedly to the Gulf of Mexico. In all this distance of 2,400 miles, the descent is so uniform and gentle—so little accelerated by rapids—that when there is sufficient water to float the vessel, and sufficient power to govern it, the downward voyage may be performed without difficulty or danger in the channels as they were formed by nature; and the return trip might be made with equal security and success with very little aid from art.

And such is also the characteristic of many of the smaller ramifications of the head waters of the Alleghany, which do not rise on the borders of Lake Erie. They still descend so gradually and uniformly that they may be safely traversed by rafts and boats when reduced to a width of only twelve or fifteen feet.

The elevation of the Alleghany at Olean Point, 250 miles above Pittsburg, as determined by the surveys of

SECTION FROM THE ALLEGHANY RIVER TO LAKE ERIE THROUGH CHAUTAUQUE LAKE

Fig. 1

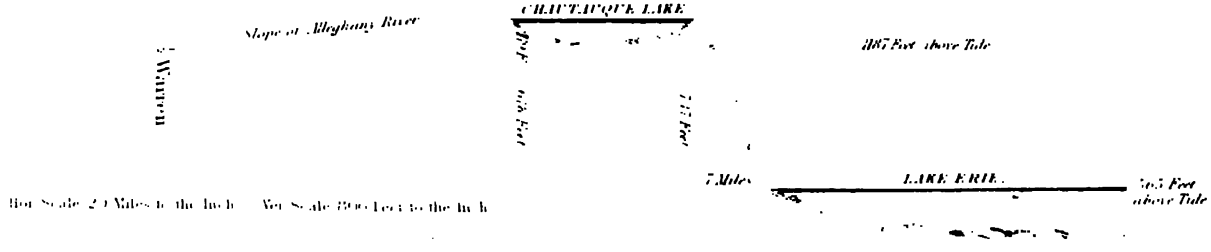
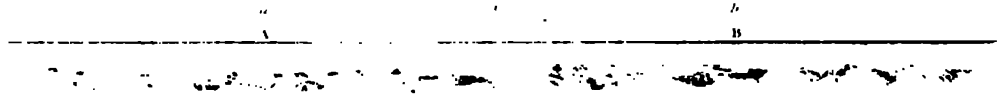


Fig. 2



SECTION FROM THE ALLEGHANY RIVER TO LAKE ERIE THROUGH CHAUTAUQUE LAKE.

Fig. 1

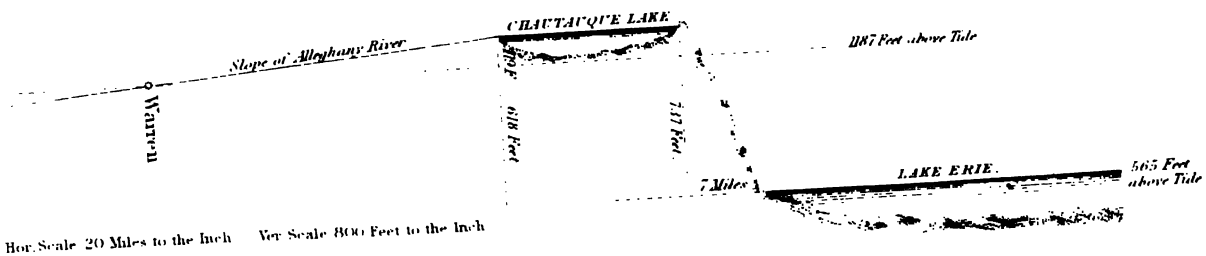
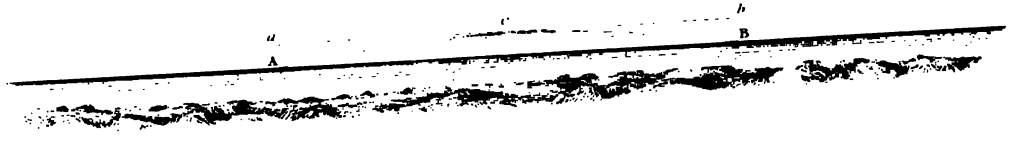


Fig 2.



the writer, is 1,403 feet above tide. Steamboats have ascended to this point—2,300 miles from the mouth of the Mississippi—in high water, and might, by a little labor, be capable of running there at all times.

The annexed section (Plate XI. Fig. 1), is a profile of the Alleghany and the outlet of Chautauque Lake, one of its tributaries, showing the physical formation of the district connecting the head waters of the Ohio River with Lake Erie.

An inspection of this diagram will exhibit the plane along which flow some of the northern tributaries of the Ohio, and the sudden depression below that plane of the basin which contains Lake Erie. It is a correct representation, drawn to a scale of forty vertical to one horizontal, from the actual surveys of the writer.

The upper Alleghany and its tributaries, traced towards their sources, rise very uniformly at the rate of about 3 feet per mile, and terminate in a number of small lakes, of which the Chautauque is the most important, and separated, like the others, by a narrow ridge from the basin of Lake Erie. An excavation only 60 feet deep through this ridge would turn one of the principal tributaries of the Ohio into Lake Erie and the St. Lawrence.

Tracing the Ohio River from Coudersport, which is some 40 miles above the extreme limit of the natural steamboat navigation of the Alleghany, to the entrance of the Mississippi into the Gulf of Mexico, we find the following rate of descent from point to point :—

TABLE V.

DESCENT OF THE ALLEGHANY, OHIO, AND MISSISSIPPI RIVERS.

	DISTANCES.	FALL.	FALL PER M.	
	Miles.	Feet.	Feet.	Inches.
From Coudersport to Olean Point	40	246	6	2
From Olean Point to Warren	50	216	4	4
From Warren to Franklin	70	227	3	3
From Franklin to Pittsburg	130	261	2	
From Pittsburg to Beaver	26	30	1	$1\frac{85}{100}$
From Beaver to Wheeling	62	49	—	$9\frac{50}{100}$
From Wheeling to Marietta	90	49	—	$6\frac{53}{100}$
From Marietta to Le Tart's Shoals	31	16	—	$6\frac{17}{100}$
From Le Tart's Shoals to the mouth of Kanawha	55	33	—	$7\frac{20}{100}$
From mouth of Kanawha to Portsmouth	94	48	—	$6\frac{13}{100}$
From Portsmouth to Cincinnati	105	42	—	$4\frac{80}{100}$
From Cincinnati to Evansville	328	112	—	$4\frac{10}{100}$
From Evansville to the Gulf of Mexico	1365	320	—	$2\frac{813}{1000}$
From Coudersport to the mouth of the Mississippi	2446	1649		

The descent of the Ohio, from point to point, exhibited in this table, is derived from the labors of numerous civil engineers, whose surveys, carried across the States of New York, Pennsylvania, and Virginia, to the Ohio River and Lake Erie, and from Lake Erie through the States of Indiana and Ohio, are the only reliable sources from which we can yet determine the entire fall of this great commercial highway.

The differences of the elevations at low water of the Ohio at Pittsburg, Wheeling, and Le Tart's Shoals, are from an hydrographical survey made under the direction of the United States Topographical Bureau.

The elevation of Olean Point, in the State of New

York, and the heights of all other places in that State, referred to in this paper, were obtained from a survey, conducted by the writer, in the first location of the western division of the New York and Erie Railroad, in 1834. That of Point Pleasant, at the mouth of the Great Kanawha, was also obtained from a survey made by the writer, for the James River and Kanawha improvement in Virginia, in 1838; which survey was carried from tide-water at Richmond, across the Alleghany Mountains, to low water in the Ohio, and tested effectually from point to point.

The levels of the Alleghany at Coudersport and Warren are computed from facts obtained from the survey of the Sunbury and Erie Railroad, made in 1839, under the direction of Edward Miller, Esq., civil engineer.

The elevation of low-water in the Ohio at Pittsburg is variously stated by different authorities. Preference is here given to the levels made under the direction of Messrs. Nathan S. Roberts and Alfred Cruger, in 1829, for the Chesapeake and Ohio Canal Company.

The elevation of the low-water surface of the Mississippi, at the mouth of the Ohio, is derived from the recent survey of the Mobile and Ohio Railroad, made under the direction of Captain John Childe, civil engineer.

The level of Lake Erie, which forms the basis for the determination of heights west of the Ohio, was first correctly obtained in the location of the Erie Canal, and reported at 565 feet above tide.

The elevation of that lake, as determined by the survey of the New York and Erie Railroad, was 569 feet above tide.

The following table exhibits the elevations of prominent points along the Ohio and Alleghany Rivers above the level of the Atlantic. The writer regrets his inability to give to the respective engineers by whom the surveys were made proper credit for their labors.

TABLE VI.

ELEVATIONS OF THE OHIO RIVER AT LOW WATER.

	FEET ABOVE TIDE.
Mouth of Ohio, above high tide, in Gulf of Mexico	275
Mouth of Wabash (approximately)	297
Evansville (approximately)	320
New Albany, below the Falls	353
Louisville, above the Falls	377
Cincinnati	432
Portsmouth	474
Mouth of Great Kanawha	522
Head of Le Tart's Shoals	555
Marietta (mouth of Muskingum)	571
Wheeling	620
Pittsburg	699
Franklin	960
Warren	1,187
Chautauque Lake	1,306
Olean Point	1,403
Mouth of Oswaya	1,419
Smithport	1,480
Coudersport	1,649
Surface of Lake Erie	565

Cairo, at the mouth of the Ohio, is computed to be 1,178 miles from the Gulf of Mexico. The descent of

the Mississippi, from the mouth of the Ohio to the Gulf of Mexico, is, therefore, $2\frac{8}{10}$ inches per mile, at low water. It has already been stated (page 23) that the average descent at high water, is 3¼ inches per mile.

From Cairo to Pittsburg the ascent is 424 feet, and the distance 975 miles. The average inclination of the Ohio is, therefore, $5\frac{2}{10}\frac{1}{0}\frac{8}{0}$ inches per mile.

From Pittsburg to Olean Point the ascent is 704 feet, and the distance 250 miles. The average inclination is, therefore, 2 feet 10 inches per mile.

The distances from point to point along these rivers are not obtained from actual survey, but are the computed distances as they are estimated by watermen, or laid down in the rough charts of the river. While, therefore, we may regard the elevations of the low-water surface of the stream as correctly ascertained, we can only consider the fall per mile, deduced from these distances, as close approximations.

The descent of the Mississippi, below the mouth of the Ohio, at low water, may be confidently taken, as above, at an average of $2\frac{8}{10}$ inches per mile; and that of the Ohio, from Evansville to its confluence with the Mississippi, at about $2\frac{9}{10}$ inches per mile.

It has been suggested that the waters of the Gulf of Mexico stand much higher than those of the Atlantic on the spheroidal surface of the earth; for the reason that the Gulf Stream, setting always towards the north, must have a certain descent to account for its current.

That current can only be due to a certain head at the source of the stream, since water in an open channel flows only in virtue of the inclination of its surface. But the levels in the foregoing table, which have been carried from the Hudson to the mouth of the Wabash, and from the Gulf of Mexico to the mouth of the Ohio, agree so closely, that, while we cannot dispute the theory, it is impossible, yet, to detect the fact.

By observing the descent of the Alleghany from Franklin to Pittsburg, we may conclude that rivers, of which the fall does not exceed two feet per mile, are navigable for steamboats, unless there be great irregularity in the distribution of that fall. In the event of such irregularity existing, rivers having an average descent not exceeding two feet per mile, if well supplied with water, must afford exceedingly good navigation between the rapids, which must be very remote and easily overcome.

We learn, also, from these tables, that a descent of nearly *four feet per mile* is not incompatible with the existence of steamboat navigation, if the supply of water be well maintained; for a steamboat has ascended the Alleghany as far as Olean Point, overcoming in places a slope of nearly five feet per mile.

It is well known that the navigation of the Ohio, which, at certain seasons, is scarcely surpassed on living streams, often fails for want of water of sufficient depth to float the boats that can be most advantageously used. It has been proposed, at times, to remedy this defect by leading the water of Lake Erie into the Ohio,

and maintaining the navigation by supporting the depth in the channel from that ample source. But it will be perceived by an inspection of the foregoing table, that the Ohio River at Pittsburg is, at low water, 134 feet *above* the level of Lake Erie; and that the plane of the surface of that lake, extended to the south, will pass 700 feet below the sources of the Alleghany, 395 feet below the town of Franklin, 134 feet below Pittsburg, 55 feet below low water at Wheeling, and would cut the plane of the Ohio between Parkersburg and Marietta, and at a point about 100 miles south of Lake Erie.

It is not at all necessary to refute this proposition as a practical measure; but it is useful to extend the plane of the lake, so as to ascertain what positions it commands in the valley of the Mississippi. It is by carrying such levels over the country that we best illustrate and best learn to appreciate the great features of its physical formation.

While it would be impracticable to turn the waters of Lake Erie into the Ohio, nothing would be more feasible than to divert all the head waters of the Alleghany from their course, and precipitate them over the borders into the basin of Lake Erie, down a slope of more than 700 feet in perpendicular height, and in a succession of cataracts that would rival Niagara in sublimity.

Such a work might be productive of no useful result, but it could be effected more easily than many other undertakings that have been successfully achieved in this country.

PROFILE OF THE OHIO AND ITS TRIBUTARIES.

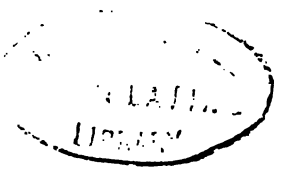
The accompanying diagram (Plate XII.) will illustrate the comparative slopes of the Ohio River and its principal tributaries, and serve in some degree to exhibit their relative susceptibility of improvement. The reader will not fail to observe the regularity and symmetry of the curve in profile, formed by the line of descent followed by the Ohio and its chief prolongation, the Alleghany River. From the summit of the Alleghany Mountains, where the slender tributaries of this arm of the Mississippi rise opposite to those of the western branch of the Susquehanna, down to the mouth of the Ohio, this great river flows with almost unbroken regularity. Rapid at first where it leaves the mountain sides, it becomes more and more gentle in each hundred miles of its way, until its accumulated waters flow into the Gulf of Mexico.

But the beautiful adjustment of this great artery of commerce can be best appreciated by a comparison of its profile with that of other important rivers, even of its own family.

The Great Kanawha is one of the largest tributaries of the Ohio, into which it flows at a point computed to be 714 miles above the confluence of the latter stream with the Mississippi. If we examine this river on the profile, we shall find that it descends more rapidly than the Ohio, even in the first section of 87 miles above its embouchure; but still, for that distance, up to the foot

Plate 12

Ohio & Ohio Canal Summit
PENNSYLVANIA.
2554 ft
Summit
Cross Creek Summit
VIRGINIA
2075 ft.
Little River
Forks of Roanoke
1178
Smithfield
1262
Connellsville
865
Youghiogeny River
Franklin
Allegany
Warren
River
Clean Point
Simemahoning Summit
PENNSYLVANIA.
1899 ft.
Coudersport
Pittsburgh
Monongahela River
Virginia & Penn. Line
774
960
983
1187
1263
1670
OCEAN LEVEL



of Loup Creek Shoals, possessing the general characteristics of its recipient. For that distance, also, the Great Kanawha is either navigable, or susceptible of being made permanently so by furnishing its channel an abundant supply of water.

But, in the vicinity of the Falls, the character of this river suddenly changes. The profile here mounts up with a quick ascent, which renders idle all expectation of stemming the current. The stream becomes, in fact, a succession of rapids, falling through 362 feet in a space of $27\frac{3}{10}$ miles, which is about twenty-seven times as much as the Ohio falls in the corresponding portion of its course. It is, in fact, more than the descent of Niagara River from Lake Erie to Lake Ontario, which, in the same space of about 27 miles, passes over the Falls, and descends through rapids almost as sublime as the cataract itself.

A further inspection of the profile of the Kanawha exhibits another fact somewhat remarkable in the descent of this great river.

The acclivity of the Ohio, and that of its tributaries, increase continually as we ascend towards their sources—forming, instead of a plane, a very uniform curve in profile, presenting its *concave* surface upwards. But the outline of the Great Kanawha, from the commencement of the rapids, where it assumes a new character and the name of New River, is the reverse of this arrangement—the slope of that remarkable stream becoming less and less abrupt the nearer we approach its source, up to the very base of the Alleghany Mount-

ains, and its profile presenting the form of a curve *convex* to the horizon. The scene of this anomaly in the descent of great streams commences, as we ascend, at the passage of New River through the Gauley and other mountains, where stone cliffs of unrivalled height and beauty confine the torrent.

The same peculiarity is observed also, though in a less marked degree, in the profile of the Greenbrier, a tributary of New River; but, with these exceptions, all the great arms of the Ohio obey the law which prevails in the slope of their common recipient, increasing in their acclivity from their mouths to their sources, and often so regularly that the ordinates of increase might be closely represented by an equation of little complexity.

Looking along the profile from east to west, we find the elevation of the dividing ridge between the waters which flow into the Gulf of Mexico, and those which reach the Atlantic through the lakes and the St. Lawrence, highest at the sources of the Alleghany, in the State of New York, and falling away as we pass along the borders of the lakes towards the Mississippi.

The height of the summit which divides the waters of the Genessee, flowing into Lake Ontario, from those of the Alleghany, near the village of Friendship, is 1678 feet above tide;* further west, that which divides Bear Lake, at the head of the principal branch of the Connewango, from Lake Erie, is 1320 feet;* still fur-

* Surveys of Charles Ellet, Jr.

ther west, the natural summit between Conneaut Lake and the harbor of Erie, in Pennsylvania, is 1095 feet; and proceeding further to the westward we find the surface still more depressed, and the country assuming more and more the appearance of a plane as its level descends.

The summit between the Muskingum and Cuyahoga, in Ohio, is but 990 feet above tide; that between the Sandusky and Scioto, also in Ohio, and further west, is 923 feet; the dividing ground between the Wabash and Maumee, in Indiana, is reduced to 745 feet; and, finally, that between the Illinois River and Lake Michigan is but about 610 feet above the level of the sea.

Proceeding from the Ohio to the west, the plane of the country descends towards the Mississippi, where, as before described, it intersects the great plane which forms the bed of the western tributaries of the Father of Rivers. In fact, the great slope from north to south has here, also, a dip from east to west, partaking of the general inclination of the country which prevails from the summit of the Alleghany Mountains to the bed of the Mississippi.

This profile must be regarded as a beautiful practical illustration of the accuracy of the spirit-level. Many of the elevations which it exhibits have been obtained by lines of survey carried from the Hudson to Lake Erie, and from Lake Erie, through Ohio, Indiana, and Illinois, to different points along the Ohio River; others, by surveys across the mountains of Pennsylvania and Virginia, made by different agents, and requiring the

transfer of some fifteen or twenty thousand different observations. Yet these results, continued as the levels have been along lines of five hundred, and in some instances more than a thousand miles in length, are so accurate and consistent, that when the writer had projected in profile the elevation of a point on the Ohio only *sixteen feet* in error, he was enabled to detect the discrepancy, and obtain an authentic result in conformity with other established facts.

It is not practicable to exhibit even all the principal tributaries of the Ohio on the same profile, without producing confusion. They must be compared, therefore, by their respective inclinations and developments.

The TENNESSEE RIVER is, without question, the first in magnitude and importance, and destined when improved, as it will probably hereafter be, and connected by railroads with the great valley of Virginia, and the seaports of South Carolina, Georgia, and Alabama, to perform a part in the commerce of this Union more important than that of any other stream, save the Ohio, from the Atlantic to the Mississippi.

The mouth of the Tennessee is computed to be 45 miles from that of the Ohio; and its low-water level is there about 286 feet above the Atlantic. Its elevation at Chattanooga is 643 feet above tide;* and the average descent of the stream below that place is about seven inches per mile.

The elevation of the Holston, the principal tributary

* Surveys of J. Edgar Thomson, civil engineer.

of the Tennessee, is 1914 feet above tide at Seven Miles Ford, in Virginia;* and the fall of that portion of the river, between Seven Miles Ford and Chattanooga, is about two and a half feet per mile.

The summit which separates the head waters of the Tennessee from those of New River, at Mount Airy, is 2,563 feet above the Atlantic.*

CUMBERLAND RIVER is the next most important arm of the Ohio, which it enters only 16 miles above the mouth of the Tennessee. The elevation of low water is here about 284 feet above tide.

The surface of the Cumberland, at Nashville, is 388† feet above the Atlantic, or 104 feet above the mouth of the river. The distance by the river, from its entrance into the Ohio, to Nashville, is 240 miles, and the average fall, therefore, 6½ inches per mile—very nearly the same as that of the corresponding portion of its sister stream, the Tennessee, but about twice as great as that of the Ohio below the falls, and that of the Mississippi below the mouth of the Ohio.

The WABASH, next in succession, but perhaps equal in volume to the Cumberland, is the largest of the tributaries of the Ohio which descend along its northern plane. The elevation of low water at the mouth of the Wabash is 297 feet above tide. In the first 91 miles, extending from its confluence with the Ohio to the

* Surveys of C. Crozet, civil engineer.

† From surveys of J. Edgar Thomson and James H. Grant, civil engineers.

mouth of White River, the fall is 57 feet, or 7½ inches per mile.*

The foot of the "Grand Rapids" is one mile above the mouth of White River. These ripples have an aggregate fall of 10 feet, distributed over a space of eight miles.

The inclination of this great river from point to point is exhibited on the profile. The total descent from the mouth of Little River to the Ohio, a distance computed at 370 miles, is 385 feet, or a small fraction over 12 inches per mile.†

It is worthy of observation that the rate of descent of the tributaries of the Ohio increases very nearly in proportion to the increase of the slope of the Ohio itself, as we ascend from its mouth to its source. Those rivers which enter below the Falls have gentler currents than those which enter above the Falls; and those which enter above the Falls are more languid than those which come in near the head of the stream.

The rate of descent of all these navigable tributaries, near the Ohio, is about twice as great as that of the Ohio itself where joined by the respective tributaries. Thus, the Tennessee, and Cumberland, and Wabash, have each a descent of about 7 inches per mile, while the average slope of the Ohio below the Falls is 3 inches per mile. We shall find other examples of

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* Letter of Sylvanus Lothrop, civil engineer.

† Report of J. L. Williams and Howard Stansbury, civil engineers.

this rule as we ascend; but the next river in order is an exception which justifies explanation.

GREEN RIVER enters on the left border of the Ohio, from the State of Kentucky. The average inclination of this stream, from Bowling Green, on Barren River, a tributary of Green River, to its mouth—a distance of 175 miles—is 4⅛ inches per mile. The actual fall in this distance is 60 feet, and the rate of inclination but one-third greater than that of the lower Ohio.

To comprehend the structure of the country and the cause of this exception, we must bear in mind that there is a continuous slope, approximating to that of a great plane, and extending from the summit of the Alleghany range, continued south, down to the bed of the Ohio. But the prolongation of that dividing range sweeps round through the western end of North Carolina and the northern portions of Georgia and Alabama, until it acquires a nearly due west direction along the southern bend of the Tennessee River. In fact, this great stream follows the course of the mountain range which divides the waters of the Atlantic from those of the Mississippi, and serves to mark its general outline.

Cumberland River then sweeps in an interior circle, somewhat concentric to the bend of the Tennessee, and consequently rests lower down upon the great slope which extends from the summit of the dividing range to the vale of the Ohio.

It occupies a lower level than the Tennessee; while Green River follows yet an interior circle, concentric both to the sweep of the Cumberland and that of the

Tennessee, and rests nearer to the foot of the same great plane than either of the exterior rivers, and approaches consequently closer in position and level to the bed of the Ohio.

If we proceed from the Ohio in a south or south-eastern direction, crossing the valleys of Green River, the Cumberland, and the Tennessee, successively, we shall be constantly ascending to a higher and higher level; although the route leads over many intermediate elevations and depressions, all resting on the same common slope, which, as before explained, extends from the crest of the dividing ridge to the valley of the Ohio.

For this cause—resting near the foot of the great plane, and running nearly parallel with the course of the Ohio—Green River has a descent less rapid than that of the more elevated beds of the Cumberland and Tennessee, and more rapid than that of the Ohio.

KENTUCKY RIVER is the next important tributary which we find on ascending towards the north. The distance by the meanders of this stream, from Three Forks to its mouth, is 257½ miles, and the total fall 216 feet, or 10 inches per mile.

The slope of the Ohio between Cincinnati and Louisville is 4½ inches per mile, in accordance with the usual relation between the fall of that stream and the rates of descent of its navigable tributaries.

LICKING RIVER, Big Sandy, and the Guyandotte, can hardly be called navigable rivers. They are streams of an inferior class, and obey a rule so general that it almost amounts to a law, viz., that, under like circum-

stances, the smaller the tributary of the Ohio, the greater is its descent; a rule which holds, with few exceptions, whether the branch enter directly into the principal stream, or reach it indirectly through an affluent of superior magnitude. The largest streams run in the lowest valleys, as if they had made for themselves the deepest channels in the earth.

The Licking River, from West Liberty to the Ohio, a distance of 231 miles, falls 316 feet, or 16½ inches per mile; while Guyandotte River, from Logan's Court-House to the Ohio, a distance of 74 miles, falls 142 feet, or 23 inches per mile. These streams are of about the same class, yet the descent of the former is much the least rapid, as it ought to be, under the assumption that they both descend along the slope of the great plane which reaches from the Alleghany to the Ohio. The Licking crosses the plane obliquely, and descends it gradually; while the Big Sandy and the Guyandotte take a course at right angles to the axis of the mountain ridge, and obtain, therefore, more nearly, the proper inclination of the plane.

The GREAT KANAWHA, the next in succession, is a navigable river, and is correctly represented in the profile. From Loup Creek Shoals to the mouth of the river is 89 miles, and the descent 86 feet, or very nearly 12 inches per mile.* The fall of the Ohio, from the mouth of the Kanawha to Cincinnati, is $6\frac{13}{100}$ inches per mile—in conformity with the rule.

* Surveys of Charles Ellet, Jr.

The LITTLE KANAWHA, from Bulltown to Elizabethtown, 108½ miles, falls 181 feet; and from Elizabethtown to the Ohio, 27½ miles, the fall is 28 feet, or 12½ inches per mile.* The descent of the Ohio below Marietta is $6\frac{17}{100}$ inches per mile.

The SCIOTO is not navigable. The distance from Columbus to Portsmouth is about 100 miles by water, and the fall 302 feet.

The MUSKINGUM, from Zanesville to Marietta, about 60 miles, falls 104 feet.

WHEELING CREEK is a very small tributary, and, like other small tributaries, has a rapid descent. From low water in the Ohio to the mouth of Wolf Run, a distance of 17 miles, the fall is 206 feet, or 12 feet per mile.

The ALLEGHANY RIVER, as already shown, descends from Franklin to Pittsburg at the rate of 2 feet per mile; while the Ohio, after receiving its great tributary, flows off with a fall of but little over 1 foot per mile. But the Monongahela, the other great arm, contrary to the rule, and unlike every other tributary, has a descent more gentle even than that of the Ohio itself. The fall of this river, in the 91 miles extending from the Virginia State line to Pittsburg, is 75 feet, or at the average rate of 10 inches per mile. From Weston to the State line, a distance of 107 miles, the fall is 223 feet, or a fraction over 2 feet per mile.

A reference to the map, with constant regard to the

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* Survey of C. Crozet, Esq.

fact that there is a continuous though irregular plane, reaching from the Ohio to the summit of the Alleghany Mountains, will account for this anomaly.

The course of the Monongahela, from its source to its confluence with the Alleghany, is almost due north; and, consequently, in ascending from its mouth to its source, we double upon the course of the Ohio, keeping a direction parallel with that river, and also with the axis of the great dividing ridge. But the Ohio, which marks the foot of the plane, and the summit of the Alleghany, which marks its upper edge, both have a dip to the south; and the Monongahela, running due north, is therefore surmounting the dip while its surface is descending to the Ohio.

The same considerations apply also to Tygart's Valley, of which the general direction coincides very nearly with that of the Monongahela—both running parallel with the Ohio, but in the opposite direction. But Tygart's Valley lies east of the Monongahela, and higher up on the great slope, while it breaks through the ridge of Laurel Hill, and follows the valley lying between that ridge and Cheat Mountain. Its fall is, therefore, greatly increased, and amounts to 150 feet in the first 20 miles above its junction with the Monongahela, or 7½ feet per mile.*

Cheat River, a more important stream than Tygart's Valley, lies still further east, and runs nearly parallel with that stream as well as with the Monongahela, in a

* Surveys of Benjamin H. Latrobe, civil engineer.

valley inclosed between the Cheat and Greenbrier Mountains. The fall of this stream is 600 feet in the first 47 miles above its confluence with the Monongahela.*

These mountain ridges and intermediate valleys, and their streams, all run parallel with the crest of the Alleghany, and all rest on the great slope which descends from the summit of that mountain ridge towards the Ohio.

The summit of the Alleghany at the lowest passes, near the sources of the Greenbrier and Cheat Rivers, may be stated at . . .	2,400 ft. above tide.
The surface of Cheat River, near the north-western turnpike, at	1,375 " " "
The surface of Tygart's Valley, in the same latitude, at	1,000 " " "
The surface of the Monongahela, in the same parallel, at	910 " " "
The surface of the Ohio, above Parkersburg, at	570 " " "

Descending from the Alleghany to the west, we thus find each stream we cross, in the same parallel, occupying a lower level, until we reach the Ohio, at the foot of the slope. The breadth of this great plane, from east to west, is very uniformly 125 miles, and the total descent in that distance about 1,800 feet, or at the average rate of 14½ feet per mile.

If we now turn to the opposite plane, in Ohio, and assume for the level of its origin the summit which separates the waters which flow into Lake Erie by the Sandusky, from those of the Scioto, or 923 feet above

* Surveys of Benjamin H. Latrobe, civil engineer.

tide, and for that of the foot of the slope, the level of the Ohio at Portsmouth, we shall again find the distance about 125 miles, but the descent only 450 feet, or $3\frac{6}{10}$ feet per mile.

The average inclination of the great plane from the east and south, is, therefore, four times as great as that of the great plane from the north.

The Ohio River thus occupies middle ground in the wide valley which it drains, and the waters which it serves to shed are supplied in very nearly equal quantities by its northern and southern slopes.

OF THE DRAINAGE OF THE OHIO

We are but little aided in the determination of the facts attending the drainage of a country, and the discharge of its rivers, by the previous labor of philosophic writers. The investigations of this subject have been confined, almost exclusively, to the measurements made by engineers of the volume of water which certain inconsiderable streams would furnish during periods of drought, for the use of navigable canals depending on them for supply. No systematic experiments on a large scale, with a view to the determination of the daily and annual discharge of great rivers, and the comparison of that discharge with the annual fall of rain for the climate, so as to obtain the amount consumed by vegetation and evaporation, over wide areas, have ever yet been instituted.

There has, perhaps, never been presented any practi-

cal or commercial enterprise, depending on these facts, to elicit an investigation necessarily laborious and costly. The experiments of the writer on the discharge of the Ohio at Wheeling will, it is hoped, to some extent, supply this void, and furnish a basis for valuable scientific and economical conclusions.

These experiments were prosecuted during the spring and summer of 1849, for the purpose, mainly, of ascertaining the practicability and cost of supporting the navigation of the Ohio, by supplying the channel with water from reservoirs properly constructed upon its tributaries. The results, it is believed, are not only valuable in establishing this fact, but also of interest as contributions to theoretical and practical science.

The site chosen for these experiments was a space along the Ohio, from the village of Martinsville, above Wheeling, to the Burlington quarries. A portion of the river, 10,063 feet in length, was measured off and divided into four sections. This portion was carefully surveyed and sounded. The width of the surface was determined from point to point by triangulation with a theodolite, and the depth from a series of several hundred soundings.

The observations for the velocity were made on a float properly loaded, and suffered to descend by the force of the current in the thread of the channel. The observer kept alongside of the float, and followed it down in a small steamboat, of which the writer then had control, noting the time as it passed the ranges pre-

viously established at the several stations on the Ohio and Virginia shores.

The height of the water at the time of each observation was carefully marked, and subsequently determined by the spirit-level; and the corresponding depth upon the bar at Wheeling was simultaneously noted, so that all the discharges might be computed with reference to the depth upon that bar. Due precaution was observed to insure accuracy, by so adjusting the float that very little surface should be exposed to the action of the wind—a source of error in such observations exceedingly difficult to obviate. Finally, care was taken to put the float in the thread of the channel, and to endeavor to select suitable weather for each observation.

With all these precautions errors and discrepancies were unavoidable, and it was only by industriously multiplying observations that their effects could be adequately neutralized.

The first experiment was made on the top of the flood of May 8, 1849, when the water stood $31\frac{25}{100}$ feet upon the bar at Wheeling. The observations were continued frequently as the water fell, so as to obtain experimental results for numerous stages, from a flood of 31¼ feet down to a depth of $2\frac{3}{10}$ feet on the bar.

The value of the discharge was determined by multiplying the area of the reduced prism of the channel corresponding with each stage, by the observed velocity—both in feet—and correcting by De Prony's formula for the difference between the surface and the mean velocity of the stream. But to ascertain the

volume of water discharged at *every* stage of the river, it was necessary to have the means of deducing from the experimental results, corresponding with given depths on the bar, the volumes which must pass down at every intermediate stage. For this purpose, it was essential to construct an empirical formula, which should agree with all the correct results obtained from actual measurement, and thus permit the interpolation of the quantities due to the intermediate depths.

The following equation fulfils that purpose: in which,

d represents the reduced depth of the river, in feet, in the section upon which the velocities were measured; and,

D is the corresponding discharge per hour, in cubic feet, when the reduced depth is d. Then,

$$1{,}083{,}000\ d^2 - 10{,}000\ d^3 = D$$

or the number of cubic feet hourly discharged when the depth is d.

This formula agrees satisfactorily with the observed discharges for all the reduced depths at which observations were taken; and, within those limits, may be used in preference to the observations themselves, and to interpolate for heights intermediate between the observations. But, having a maximum value, it would not be admissible to extend its application very far beyond the range for which it was constructed. There is, in fact, no maximum to the discharge, while the value of d, or the depth of water, increases.

The following table exhibits, side by side, the quan-

tities discharged, as determined by this formula, and those calculated for the same depths from the observations.

The second column represents the depth on the bar in the channel at Wheeling; the third, the corresponding reduced depth at the place of observation; the fourth, the observed velocity of the float; the fifth, the discharge in cubic feet per hour, as determined by actual gauging; and the sixth is the calculated discharge, or the value of D.

The average width of the river in the section where the velocities were determined was 1,066 feet, when the depth on the bar was $5\frac{38}{100}$ feet, and, of course, varied irregularly with the depth.

The writer takes this occasion to express his obligation to his friend and valuable assistant, I. Dickinson, Esq., civil engineer, for much aid in making the observations of which the results are recorded in the annexed table.

At a later date, Mr. Dickinson also acted as assistant engineer in the investigations touching the overflows of the Delta of the Mississippi; where his services were again of great value in making the numerous measurements for the memoir on that subject, which forms the first part of this volume.

TABLE VII.

OF THE CALCULATED AND OBSERVED DISCHARGES OF THE OHIO RIVER AT WHEELING.

No. of observations.	Depth of water on the bar at Wheeling.	Reduced depth at place of observation, or value of *d*.	Velocity of central current in feet per hour.	Discharge in cubic feet per hour ascertained by observation.	Discharge in cubic feet per hour calculated by formula.
1	2.20	3.43	3,594	10,158,000	12,338,000
2	2.72	3.85	3,552	11,268,000*	15,487,000
3	3.55	4.60	5,890	22,650,000†	21,887,000
4	3.71	4.75	5,030	20,100,000*	23,300,000
5	4.20	5.18	5,095	22,270,000*	27,580,000
6	4.89	5.85	6,708	33,300,000	35,000,000
7	5.38	6.31	6,423	34,560,000	40,495,000
8	5.55	6.48	7,564	41,600,000	42,640,000
9	5.72	6 65	8,356	47,300,000	44,820,000
10	6.72	7.65	9,196	60,000,000	58,723,000
11	7.92	8.82	11,028	83,000,000	77,140,000
12	9.66	10.51	12,804	118,400,000	108,100,000
13	11.04	11.84	14,946	156,400,000	138,700,000
14	11.31	12.10	14,637	154,000,000	140,000,000
15	15.06	15.74	16,500	226,000,000	229,000,000
16	20.76	21.22	20,126	378,000,000	391,000,000
17	25.16	25.45	23,222	530,000,000	535,000,000
18	27.92	28.16	24,000	611,000,000	632,300,000
19	31.25	31.41	24,644	736,000,000	758,300,000

It will be found, on inspection, that there are several irregularities in the table. In two instances the velocities exhibit a slight increase, although the depths in the channel were diminished. In some instances the float left the thread of the stream, and was consequently somewhat retarded.

In the lower velocities the irregularities are very considerable, and were caused altogether by the wind. It was almost impossible to obtain observations, when the water was very low, which were not disturbed by this

* Head wind. † Wind down stream.

cause. The experiments, in this state of the river, consumed from two to three hours, and the exposure of the float during all that time, to the slightest breeze, affected the result materially. This could not be obviated by depressing it beneath the surface of the water, for the surface of the water itself was also retarded. These discrepancies are inseparable from the subject. Yet we shall find, by summing up all the computed and all the observed quantities, that in the aggregate they agree almost precisely. The formula represents the mean of many observations, and is therefore more to be relied on for every stage of the water, than any single experiment that can possibly be made expressly for a given stage.

The objects of the research required that we should possess a convenient means of determining the actual discharge of the Ohio River in every condition of its waters, and for every day during a series of years.

The following table has been constructed for this purpose, from the foregoing formula, modified to express the diurnal instead of the hourly discharge. The table exhibits only the volume due to each foot in height, and of course will require interpolations for the fractions of feet. It is extended from common low water up to a flood of 36 feet—the highest, save one, which has been known in the Ohio, at Wheeling, for the space of a quarter of a century.*

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* This refers to the famous flood of 1832. But since the publication of the original edition, another flood—that of April, 1852—has been witnessed in the Upper Ohio, approaching within about 10 inches of the height of the former.

The scientific reader will recognize the utter impracticability of framing an empirical equation, which shall express minutely the volume of water flowing in a channel confined by such rude and irregular surfaces as the bed and borders of a great river. The writer, not wishing to affect a precision incompatible with the nature of the problem, has neglected the small decimals in carrying out the calculations for the construction of this table, taking care merely to preserve accuracy to the third place, so as to avoid any error equal to one per cent. of the discharge indicated by the formula for any given stage of the river.

The following equation, in which d is put for the reduced depth in feet, and D for the diurnal discharge of the river in cubic feet, will represent the volume of water flowing down the Ohio, at Wheeling, in a period of 24 hours, with as much precision as can be desired for any practical purpose.

$$26{,}000{,}000\,d^2 - 240{,}000\,d^3 = D.$$

The equation, in this form, is more convenient for application than the preceding.

In Table VIII., the figures in the third column show the number of cubic feet of water flowing past Wheeling, corresponding with the depths on the bar, which are given in the first column.

TABLE VIII.

SHOWING THE VOLUME OF WATER DISCHARGED BY THE OHIO RIVER IN 24 HOURS AT GIVEN DEPTHS ON WHEELING BAR.

Depth in feet on Wheeling bar.	Reduced depth where gauged.	Discharge in 24 hours in cubic feet.
1.00	2.00	102,000,000
2.00	3.00	228,000,000
3.00	3.98	400,000,000
4.00	4.97	620,000,000
5.00	5.96	864,000,000
6.00	6.95	1,164,000,000
7.00	7.94	1,511,000,000
8.00	8.92	1,890,000,000
9.00	9.90	2,314,000,000
10.00	10.86	2,754,000,000
11.00	11.82	3,225,000,000
12.00	12.78	3,726,000,000
13.00	13.74	4,279,000,000
14.00	14.71	4,854,000,000
15.00	15.68	5,480,000,000
16.00	16.64	6,103,000,000
17.00	17.60	6,744,000,000
18.00	18.55	7,413,000,000
19.00	19.50	8,100,000,000
20.00	20.46	8,819,000,000
21.00	21.40	9,556,000,000
22.00	22.38	10,333,000,000
23.00	23.35	11,120,000,000
24.00	24.32	11,922,000,000
25.00	25.30	12,752,000,000
26.00	26.28	13,640,000,000
27.00	27.26	14,444,000,000
28.00	28.24	15,322,000,000
29.00	29.22	16,228,000,000
30.00	30.20	17,088,000,000
31.00	31.16	17,972,000,000
32.00	32.10	18,760,000,000
33.00	33.00	19,700,000,000
34.00	34.00	20,624,000,000
35.00	35.00	21,600,000,000
36.00	36.00	22,500,000,000

The foregoing table, with interpolations for the fractions of feet, supplies a convenient means of determining the daily discharge of the Ohio at Wheeling for any given depth upon the bar at that place.

But to make practical applications of the information which it contains, we need an authentic account of the daily height of water upon the bar, to which the table refers, for a series of years. And this has, fortunately, been procured.

By reference to the books of the wharf-master of the city, the files of the *Times* newspaper and the minutes of the Reporter, the writer has succeeded in obtaining an almost unbroken record of the daily depth upon the Wheeling bar, from the year 1838 down to 1848, including both.

The heights of the water were measured up to 16 feet, on a monument established by the city authorities, under the inspection and by the levels of Captain (now Major) Sanders, of the U. S. Corps of Engineers. The height of the flood of 1832, the highest ever known, has been repeatedly and carefully levelled, as have also the marks of numerous other intermediate freshets. These heights have been compared with the record, and the agreement has been such as to impart entire confidence in the care with which the observations have been noted.

Some of these records will be found in the succeeding pages, and will furnish, it is hoped, the basis of conclusions interesting to science as well as valuable to the commerce of the country.

In the following tables, the height of the water on the Wheeling bar is shown for each day of the year to which the respective tables apply. At the foot of the column, which exhibits the record of the daily height for each month, is shown the total discharge in cubic feet for the whole of that month. The figures below the monthly discharge, in the same column, represent the height which might have been maintained throughout the month, if the water which passed down the river in that time had been discharged uniformly. These tables further exhibit the total annual discharge in cubic feet, and the constant height which might have been maintained upon the Wheeling bar throughout the year, if that discharge had been regulated by art and made uniform.

This important and interesting inquiry is believed never to have been made for any other river with equal care and accuracy; if, indeed, any authentic experiments of the kind have ever before been instituted at all.

The primary object of the writer was, as already stated, to determine the volume of water discharged by the Ohio at given stages, with a view to decide on the practicability and cost of supplying the deficiency, in times of drought, from stores reserved in artificial lakes from the superabundance which is wasted during floods, so as to maintain the navigation effectually throughout the year. Yet, in the progress of the investigation, other important and equally interesting problems very naturally arose for solution. It was desirable, also, to measure the discharge in times of freshets, so as to be

able to judge whether, in the onward strides of science and art, we had not already reached a point where it was possible to curb and render harmless, THE FLOODS which now annually sweep through the western valleys.

On seeking to find how much water would be needed to maintain the navigation at any given height, it became important, further, to determine the *maximum height* at which it could be permanently held—a question of vast importance to the mind that views the interior navigation of this country but as a continuation of that of the ocean; and is directed forward to the day when every city upon the banks of the Mississippi, Missouri, and a portion of the Ohio, is to become a port of foreign entry, accessible to ocean steamers; when the forests of the interior are to furnish the timber, the mines of the interior the iron and coal, the workshops of the interior the machinery of the vessels, and the fertile planes of the Mississippi valley the freight, which is to be shipped from the seaports of the interior to the markets of the world.

The commercial position and advantages of this wonderful valley are sublime; and its physical capabilities deserve a far more perfect investigation than can be expected of private zeal. Still, the purposes of the writer required the solution of this interesting problem; and he was, therefore, compelled to compute, day by day, the discharge of the river for the whole year; and, to render the results more worthy of confidence, for a continuous period of six years.

The same train of inquiry necessarily led to the determination of the annual drainage, and its comparison with the annual fall of rain over the wide district covered by the tributaries of the Ohio; and, as a consequence, the annual consumption of water in the processes of vegetation and evaporation.

These results are briefly stated in this paper; and being deduced from an area of nearly 25,000 square miles, and for a series of years, they possess an interest much greater than could attach to any local or more limited inquiry.

It will be found that the expectations which led to this laborious undertaking have been fully confirmed; that the steamboat navigation of the Ohio may be permanently maintained for a very trifling outlay; and that the power of the floods also may be greatly reduced by an incidental application of the reservoirs which will support the navigation. The results show that it is quite practicable to maintain an uniform height of water in this river, and that that height may be ultimately raised, at Wheeling, to *nine feet.* (See note K.) But these more remote applications are not discussed here. The present inquiry is limited to things immediate — valuable to science, or useful to the public welfare.

TABLE IX.

RECORD OF THE DEPTH OF WATER ON THE WHEELING BAR FOR THE YEAR 1848.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	13	10	8½	17	4 7/12	11	4½	8	3 5/6	2 1/6	4 1/6	7
2	21	9¼	8	16½	4½	10¾	4½	8	3 5/6	2 1/6	4 1/6	7
3	25	9½	7¼	16½	5½	10	4½	7	3¼	2½	5½	7
4	25	9	6¾	14	5¾	7	5½	7¼	3½	2½	4 5/6	7½
5	26	8½	6½	10½	7	7	9	7	3½	2½	4½	8
6	24	7¾	5	10	8¼	5¾	9	6	3½	4	6	11
7	18	8¼	5	9½	11	5¾	10	6	3 1/6	4½	5	11
8	15	7¼	5	9	17	6½	11	5¾	3	4	4¾	11
9	13	7¼	5¾	9½	17	6	10½	5½	2 11/12	4	7¼	9
10	13	6½	6	8¾	14	5½	10½	5	2¼	3½	8¼	11
11	10	6¼	6¼	8½	13	5	9½	4½	2 5/6	3½	8	14
12	8½	6	8	8	12	4½	8¾	4¼	2½	3½	7	17
13	8	5 5/6	8	7½	13	4½	7½	4	2½	3¼	6¾	19
14	7½	5¾	11	7¼	13½	4 1/6	7	4	2 1/6	3	7	19
15	7¼	5¼	11½	7	14	3 5/6	6	3¾	2 1/6	2¾	8	17
16	8½	5	11	6½	12	3¾	5¾	3½	2 1/12	2½	10	11
17	8½	4	9	6½	11	3 7/12	5¾	3 5/12	1 5/6	2 7/12	7	13
18	16	4¾	8½	6¼	10¾	3½	5¾	3½	1 11/12	2 7/12	8	10¼
19	16	5¼	7¾	6	12	3½	5½	3 1/6	2 1/12	2 7/12	8½	10½
20	13	7	7¾	6	14½	3½	4½	3¼	2½	2 7/12	8¾	9
21	12	7	9	5¾	14	3¼	4	3½	2 5/6	2½	8	8¾
22	10	8	15	5½	13½	3 5/6	4	3½	2½	2 7/12	7	9½
23	9	14	18	5 5/6	12	4½	4¼	3¾	2¼	2 7/12	6¼	18
24	8½	14½	17½	5¾	12	5½	5½	6¾	2¾	2¼	5¾	28
25	8	16	17	5¾	15	5½	4½	5½	2¾	2 5/6	5¾	28
26	7¾	14½	16	5½	14	5¾	4½	5¼	2¼	3½	5 5/6	24
27	7¼	12½	16	5 5/12	10½	5	7½	5	2¾	3¼	7¾	23
28	7	12¼	14	5	10	4 5/6	7	5	2 5/6	3 7/12	7¾	22
29	7½	9½	16	4 5/6	10	4 5/6	6¼	4	2¼	4 7/12	9	16
30	9½	—	18	4 7/12	10	4½	5½	5	2¼	6	8½	14
31	8½	—	17½	—	10½	—	5½	4	—	6	—	14
Discharge in each month.	141,076,000,000	65,914,000,000	102,781,000,000	64,468,000,000	109,663,000,000	31,085,000,000	44,266,000,000	27,143,000,000	10,587,000,000	15,173,000,000	44,923,000,000	165,640,000,000
Eq. mo. heights.	13½	8 9/10	11 18/100	8 62/100	11 63/100	5 6/10	6 77/100	5 1/10	2 74/100	3 43/100	6 96/100	14 78/100

Annual discharge, 822,719,000,000; equiv. uniform height, 8.85.

As already explained, the foregoing table exhibits the daily height of the water on the bar at Wheeling for the year 1848; and at the foot of each column is shown the number of cubic feet discharged by the Ohio during the month to which the depths in that column apply, and also the uniform height at which the water could have been maintained by the discharge of the month, if that discharge had been uniform.

On summing up these results, we find that the total volume discharged by the Ohio at Wheeling, for the year 1848, was—

822,719,000,000 cubic feet.

Dividing this quantity by 366, we obtain for the average daily discharge for that year—

2,248,000,000 cubic feet.

If we now refer to Table VIII., or to the formula from which that table was constructed, we shall find that the daily average quantity discharged during the year, was just sufficient to have maintained the water upon the Wheeling bar at an uniform height of $8\frac{85}{100}$ feet.

The area drained by the Ohio and its tributaries, above Wheeling, is estimated in this paper at 24,337 square miles; or,

678,476,000,000 square feet.

It follows, then, if we divide the above annual discharge in cubic feet by the area drained, that the volume of water which flowed down the Ohio, at Wheel-

ing, in 1848, was just sufficient, if spread over this space, to have raised the surface $1\frac{218}{1000}$ feet; or,

$$14\frac{556}{1000} \text{ inches.}$$

Such is the value of the total drainage of the region watered by the upper Ohio for that year. The greatest monthly value was in December, when it reached

$$2\frac{92}{100} \text{ inches;}$$

and the least monthly result was in September, when it amounted only to—

$$\frac{187}{1000} \text{ of an inch.}$$

There is one other fact exhibited in Table IX., which has a most important practical application, and may be properly noticed in this connection.

It appears by the record that the water was below *five* feet in February, and also in April and May; that it was down nearly to *three* feet in June, as low as *four* feet in July, at *three and a half* feet in August, below *two* feet in September, *two feet and two inches* in October, and again at 4½ feet in November; and yet the calculation shows that the discharge was sufficient, in each of those months, excepting only September and October, to have maintained the navigation at 5½ feet, or more, throughout the month.

The volume of water which the river actually furnished in each month (with those two exceptions) was sufficient to have maintained a depth of 5½ feet on the Wheeling bar, without reserving the excess of any pre-

vious month. All that was needed to obtain and secure a minimum depth of 5½ feet for navigation, was *to regulate the actual discharge of each month.*

In September, the water was down below two feet on the bar; yet the discharge for that month alone would have maintained a navigation for boats of *two feet nine inches* draft.

In October, the water was twice down to 2 feet 2 inches, and several times below 2½ feet; yet the supply for that month, without any reserve from previous excess, would have maintained an uniform draft of 3 feet 5 inches.

The total discharge for September was .	10,587,000,000	cubic feet.
The total discharge for October . .	15,173,000,000	" "
The total actual discharge for September and October, together, amounted to .	25,760,000,000	cubic feet.

To have maintained a navigation during these two months for boats drawing 5 feet, would have required a daily supply, according to Table VIII., of 864,000,000 cubic feet; or a total, for the whole period of 61 days, of 52,704,000,000 cubic feet.

The difference between this, the quantity which would be discharged with five feet on the bar, and the quantity which was actually discharged, is then 26,944,000,000 cubic feet.

This is the volume of water which it would have been necessary to provide that year to have kept the river at a minimum height of 5 feet.

The volume here deduced from actual measurement

on an extensive scale, would very nearly fill a reservoir 107 feet deep, and covering an area of three miles square.

It would require only three dams, no larger than several of those in use on the Lehigh, to be constructed across the Alleghany, to supply the whole of this volume of water.

The writer pretends not to be able to make accurate estimates of the cost of carrying out such a suggestion without the aid of previous instrumental surveys; yet he thinks he may venture to say, from his knowledge of the great tributaries of the Ohio, that three such dams as are here alluded to can be built in the usual manner, and furnished with locks for the accommodation of the trade above, as is common on other great rivers, and be completely provided with the means of drawing off the water as it is needed, for about $450,000.

But it is not his intention to recommend the construction of dams upon the great navigable tributaries of the Ohio, until the appropriate sites upon the smaller affluents have been first exhausted.

We may now proceed to the analysis of the record of the river for the previous year (1847), which is presented in Table X.

TABLE X.

RECORD OF THE DAILY HEIGHT ON THE WHEELING BAR FOR THE YEAR 1847.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	17	9	14½	8¾	6¾	6⅛	5¼	6½	2⅜	9½	14	12
2	24	10	15	12	6⅜	6	5½	6⅛	2⅜	8½	9½	16
3	28	11	12	11	6⅜	6	4⅝	5⅜	2⅝	7	8	16
4	23	9	11	11	6¼	8½	4¼	5¼	2⅜	7	7¾	16
5	23	11½	10	10	6½	9	4⅛	4⅝	2½	7	7½	18
6	22	15	9½	9½	6¼	10¾	4	4⅜	2½	6½	7	16
7	22	14	9	9	6	9	3⅞	4⅛	2¼	6⅛	6⅛	13
8	21	11	9	11	6½	8⅛	3⅜	3⅝	2¼	6	6¼	11½
9	19	10	19	14	5⅝	8¾	3½	3⅜	2¼	6½	6	10
10	14	10½	22½	15	6	7	3½	3⅜	4	21	5⅜	10
11	12	11½	27	16	6¾	6½	3⅛	3⅜	2⅝	19	6½	18
12	9½	11	26	16	6½	6¼	3⅛	4½	2⅝	19	7½	23
13	9	10	21	16	5¼	6¼	3⅛	4¼	2⅝	13	8¾	28
14	8½	9	14	12½	6⅜	6¼	3¼	4¼	3⅝	13	8½	38
15	7½	8½	13	11½	5	5⅜	3	4½	3⅝	13	8	38½*
16	7½	8	12	9½	5⅛	5½	3 7/12	4⅛	3⅛	17	8½	35
17	11	7½	10	9½	4¾	5¼	3 7/12	5½	3⅛	17	9	30
18	15	9½	8½	8	4⅜	5⅜	3½	5½	2⅝	16½	10	25
19	16	13½	8	8	4½	5¼	3	4	2⅝	12	11	21
20	15	17½	10	7¾	4½	8½	3	4⅜	3	9½	9	21
21	11½	22	8	7	4⅜	8	2⅝	4⅝	3	8¾	9½	13
22	11	27	14	6	4	8½	3	3⅜	3⅝	7¾	8½	11½
23	10½	24½	17	6	3⅜	9	3¼	3⅜	3⅜	7	9½	10½
24	8¾	22	17	6¼	3⅜	8¾	4	3 7/12	3½	7	8¾	9½
25	8½	21	16	8½	3½	7¾	4⅜	3½	4	7	12	8¾
26	7	17	15	8¼	4	8	4⅜	3 5/12	5½	10	21	9
27	7⅛	14	12	8¼	7 7/12	6½	5⅜	3⅓	6⅜	16	32	7⅜
28	8⅛	16	10	8¼	7½	6	7½	3¼	6⅜	17	27	7⅝
29	7¾	—	9½	7¼	7	13		3½	8½	18	22	7½
30	8⅜	—	9¼	7	6½	5⅜	11	3	9	17	12	6½
31	9	—	9	—	6⅜	—	8⅜	2⅝	—	15½	—	8½
Discharge in each month in cubic feet.	159,047,000,000	139,657,000,000	152,109,000,000	85,337,000,000	33,548,000,000	46,689,000,000	27,248,000,000	21,706,000,000	18,678,000,000	122,931,000,000	110,605,000,000	224,703,000,000
Eq. mo. heights.	$14\frac{45}{100}$	$14\frac{23}{100}$	$14\frac{9}{100}$	$10\frac{20}{100}$	$5\frac{74}{100}$	$7\frac{13}{100}$	$5\frac{54}{100}$	$4\frac{33}{100}$	4	$12\frac{45}{100}$	$11\frac{93}{100}$	$17\frac{76}{100}$

Annual discharge, 1,142,258,000,000 cubic feet; equiv. uniform depth, $10\frac{8}{10}$.

* According to other authority, this flood, and that of February, 1840, should be 86 feet.

By referring to the foregoing record of heights for the year 1847, we obtain the following valuable results:—

The total drainage of the Ohio at Wheeling was—

1,142,258,000,000 cubic feet;

and the average daily discharge—

3,129,000,000 cubic feet.

From which it results, by applying the formula, or Table VIII., that if the water had all been shed uniformly, so as to maintain the river throughout the year at a constant height, that height would have been $10\frac{8}{10}$ feet upon the Wheeling bar, or, within a small fraction of two feet more than in the year 1848.

If we again divide the area drained into the volume discharged, we obtain for the year 1847 a total drainage equal to $1\frac{684}{1000}$ feet; or,

$20\frac{1}{8}$ inches.

The greatest drainage of this year, also, was in the month of December, when it amounted to—

$3\frac{98}{100}$ inches;

and the least monthly drainage was again in September, when it amounted to—

$\frac{33}{100}$ of an inch.

It appears, therefore, that the total drainage of the upper Ohio, in 1847, was about 38 per cent. greater than that of 1848; that the greatest monthly drainage of that year was 35 per cent. greater than that of 1848;

and the least monthly drainage nearly 100 per cent. greater than that of 1848.

On comparing the two tables further, we find that the irregularities were very great. In the month of October, 1847, the river discharged more than *eight times* as much water as in the same month of 1848; while the discharge for a single day—the 15th of December, 1847—was as great as that of sixty days in September and October, 1848.

The computation of the daily and monthly drainage of this year also leads to some very valuable practical observations.

In 1848, the height of the water at Wheeling frequently oscillated between 22 and 27 inches, through September and October; although, in those two months, the volume actually discharged would have maintained the navigation constantly at a depth of $3\frac{25}{100}$ feet—a depth sufficient for the movement of a respectable class of freight-boats, and consequently to protect the public against prohibitory or extravagant charges. All that was that year (1848) necessary to prevent this irregularity, was two small dams—one on each river above Pittsburg—to act as *regulators of the natural flow*. Two dams of very moderate height, and two men to control them—dams which would also have furnished an additional supply of water adequate to raise the depth, even in those months, to 4 feet—could, in all probability, be built upon those rivers for an outlay of not more than $150,000 each.

In 1847, the depth was sometimes as low as 2¼ feet

at Wheeling; yet it will be seen, by reference to the table for that year, that in each month the natural flow was sufficient, if it had been well regulated, to have maintained an uniform depth of at least four feet throughout the month.

In the month of July (1847) the depth on the Wheeling bar was frequently but 3 feet, and once less than 3 feet; yet, the discharge for that very month was sufficient to have maintained a uniform depth of 5½ feet.

In August, the depth was also reduced below 3 feet; but the aggregate discharge was sufficient to have maintained it throughout the month at 4½ feet.

In September, the water fell to 2¼ feet, and varied from that to 4 and 5 feet. The actual flow, as shown by the table—the results of which are obtained in all cases from careful calculation for each day—would have maintained the height constantly, during the whole month, at 4 feet.

Now, all that was needed to protect the navigation throughout 1847 was two small dams—one on each of the great branches of the Ohio—to create reservoirs of moderate capacity, to be vented as the river fell on the occurrence of a drought; and to catch the surplus water furnished by the small freshets which occurred during the summer, and discharge it again, as needed, into the streams below.

TABLE XI.

RECORD OF THE DAILY HEIGHT ON THE WHEELING BAR FOR THE YEAR 1846.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	3½*	17	4	10½	8	9	7	4¾	4½	2¼	5¾	14
2	3½*	23	3½	11	8½	10	8½	4½	4½	2½	5	16
3	3½*	22½	3¼	10½	13	9	11	4	4	2¾	6¾	16½
4	3½*	19	3½	9	14	9	14	3¾	4½	2 7/8	9½	20
5	7½	17	3½	7½	13	9	9	3½	4	2 7/8	16½	23
6	7¾	14	4	7	11	8½	10½	3	3¾	2 5/8	13½	20
7	7½	12½	8½	6⅞	10¾	7¾	10	2½	3½	2¼	10	20
8	8¼	10	18	6 7/8	10½	8¼	10¼	2¾	5	2⅛	8	18
9	9¾	9	20	6⅛	10¾	7¾	7¼	2 5/8	4¾	2 1/2	8	19
10	11½	8½	18	6	16	6½	6	2¾	4	2	7½	28
11	11½	8	18	6⅝	14	6¼	5½	2½	3⅝	1½	7¼	22
12	9¼	7⅓	16½	6¼	14	5¾	4 7/8	2¾	3½	1½	7⅓	18
13	9¼	6½	15½	5⅜	14	5½	4½	2¾	3¼	1¾	7⅛	15
14	8	6½	19	5⅝	13½	4⅝	4	2½	3⅛	2½	7½	12
15	7 5/8	6	35	5½	10½	4½	3 7/8	3	3	3 7/8	7⅜	14
16	6½	6	34	5⅜	9	4⅛	3⅜	3½	2½	18	7⅜	11
17	6½	6⅛	32	5½	9	4⅜	3 7/8	3	2¾	11½	7⅜	9
18	7	5	26	5½	16	4¼	3½	3¼	3	10	6½	8
19	6½	4⅝	22	5¼	16	5	3½	2 7/8	3 1/2	10	6¼	7⅝
20	7⅜	5⅛	16	5	14	4⅜	3	3½	3⅛	8¼	6½	6⅝
21	7⅜	5⅛	13½	4¾	11	5⅛	2½	6½	3 1/2	8¼	6⅜	6⅝
22	6½	4 7/8	13	4 7/8	8	4⅜	2⅜	6	3⅛	7⅝	12	6½
23	5¾	4⅛	11½	4⅝	8	4 7/8	7 7/8	7	3½	7 5/8	13	6 1/2
24	5⅝	4	13¼	4⅝	6¾	4⅛	7¼	10	3	6 7/8	13	5⅝
25	8	4⅝	12½	4⅝	6½	4	7	10	2⅝	5¾	13	5⅝
26	8	4	13½	5	5½	3½	17	11	2⅜	5¾	12	5¾
27	6¾	4⅛	13	6¼	5¼	3 7/8	16	9	2 7/8	5½	11	7½
28	7¼	4	16	8	7½	3⅝	7¾	6	2½	5	10½	10
29	7¼	—	15	7½	11½	3⅛	7½	5	2¾	4¾	10	11½
30	9⅛	—	14½	7½	12	3⅛	6¾	5½	2 7/8	4½	11	20
31	10¼	—	11	—	8½		5	5½	—	4⅛	—	18
Discharge in each month in cubic feet.	53,523,000,000	77,954,000,000	197,286,000,000	42,232,000,000	102,801,000,000	35,929,000,000	56,223,000,000	27,789,000,000	14,683,000,000	35,951,000,000	75,022,000,000	159,726,000,000
Eq. mo. heights.	7 6.9/100	10 6/100	16 4.0/100	6 7.2/100	11 1.9/100	6 1.0/100	7 8.0/100	5 1.2/100	3 4.2/100	6	9 3.5/100	14 5.9/100

Annual discharge, 879,119,000,000 cu. ft.; equiv. uniform depth, 9 2.2/100.

* Closed by ice.

The analysis of the tabulated results for 1846, shows that the total drainage of the Ohio River for that year was—

879,119,000,000 cubic feet;

and the average daily discharge—

2,409,000,000 cubic feet.

If the discharge had been uniform throughout the year, the depth of the water on the bar at Wheeling would have been constantly $9\frac{22}{100}$ feet.

The drainage from the whole surface of the country was, for the year, $1\frac{297}{1000}$ feet; or,

$15\frac{56}{100}$ inches.

The greatest monthly drainage was in March, and amounted to—

3½ inches;

and the least monthly drainage again in September, when it amounted to—

$\frac{26}{100}$ of an inch.

The practical results of the inquiry for this year, also, are exceedingly interesting. We find, by reference to the table of heights on the bar, that in the beginning of the month of January, as at the close of the previous December, the water fell to 3½ feet in the channel, and the river was then closed by ice. But experience has shown that this river never freezes at Wheeling, excepting when the water falls so low that the ice grounds on

the bars and chokes the channel. Consequently, if the proper depth of water were maintained in the river, so that the ice, instead of lodging, would be carried by a brisk current over the bars, it could not jam and form dams behind which the still water could freeze and the floating particles collect.

The whole period of low water, and consequent stoppage of the navigation in December, 1845, and January, 1846, was but 14 days; and the whole quantity of water which would have been required, over and above the actual flow, was but 660,000,000 cubic feet per diem, or 9,240,000,000 altogether for the 14 days, to have maintained a uniform depth of *six feet* constantly in the channel.

Now, there are many places upon the upper tributaries of the Ohio, where a dam forty-five feet high would form a sufficient reservoir to furnish this quantity; and an inspection of the records in this paper will show that such a reservoir may be emptied many times during every winter, with full confidence that it will be promptly replenished by the rains and melted snows.

But we observe by the table of heights for 1846, that the river was not only low at the end of December and the beginning of January, when a discharge of water was needed to carry off the ice and restore the navigation, but that it rose and fell also in February, so as again to require aid from the artificial store; that it was down also in March as low as 3⅛ feet—a depth too little for the first class of boats to run, even if empty, in safety—although the total discharge of the river dur-

ing that very month was sufficient to have maintained a uniform draft of $16\frac{4}{10}$ feet. In fact, there was but one month in the whole year in which the discharge for the month, if properly regulated, would not have preserved the depth on the Wheeling bar at more than 5 feet; yet, there were periods in eight months of that year, when boats drawing over four feet could not have run, and other periods, in the summer season, when boats drawing over $2\frac{1}{2}$ feet could not pass the bar. Still, three dams of very moderate height—not exceeding 40 feet each—and which need not be made to cost more than about $300,000, would have so regulated the discharge that the depth could never have fallen, during any part of the year, below 5 feet.

In the month of October, the depth was less than 2 feet, and for about half the month it was less than 3 feet. Yet, the volume of water which passed by Wheeling, even in October, would have maintained a uniform depth of 6 feet throughout that month.

By means of only three dams, from 40 to 50 feet high, or a greater number of smaller dimensions, a fresh supply of water could have been let into the stream in January, when the river was frozen over, which would have raised the surface, increased the velocity, and swept away the ice, and have thus restored the winter navigation. The reservoirs, it will be seen by reference to the table, would have been filled again immediately, and would have been ready, in February, to bring the water up from 4 feet to 6 feet, and again, in March, from 3 feet 2 inches to 6 feet.

At the close of March, and early in April, they would have been replenished by the melted snows, and in the course of April would have been once more needed to raise the water from 4½ feet to 6 feet—two dams of fifty feet being quite sufficient to maintain this depth. In May and June, the reservoirs would have been filled again; but about the middle of June their contents would have been required to increase the depth, then down nearly to 3 feet, and bring it up to 5, or, if desirable, to 6 feet.

In the beginning of July, the reservoirs would have been once more filled by the rains, and in the middle of the same month again drawn upon to raise the water from 2 feet 10 inches—a depth entirely prohibitory of navigation for boats of the best class—and bring it up to about 6 feet.

On the 23d of July, the natural flow from the mountains increased, the water rose to 17 feet, and the reservoir would, of course, have been filled again. But early in August, the failing supply would have called for further aid from the artificial store: the waters might have been again raised to 6 feet; and, by the 21st, the reservoirs would have ceased their discharge, and have been filled again by the swollen mountain sources.

In September, the water is always low. But the same two regulating reservoirs would, nevertheless, have kept up the depth to 5 feet until the middle of October, when a rise of eighteen feet would have filled them once more. But, near the end of October, the

supply again failed, and the depth fell to 4½ feet. The same reservoirs, having been replenished by the preceding flood, would, however, have brought it up again to 6 feet or more. In November and December, the natural flow of the river required no aid.

No less than ten times in the course of the year 1846 the navigation could have been maintained at a height, generally of 6, and never less than 5 feet, by means of three reservoirs of moderate size, of which the total cost could not exceed that of twelve or fifteen miles of ordinary railroad.

The same object may be accomplished with equal certainty, and probably for an outlay not materially greater, without the necessity of placing any dams across the principal tributaries of the Ohio. The smaller branches, nearer to the mountains, abound in eligible sites for reservoirs, where an ample store of wāter may be accumulated in numerous lakes of inconsiderable dimensions, and where no land need be submerged, nor other valuable property damaged by the works. There are some important advantages to be gained by selecting these remote sites for retaining at least a part of the store. The smaller streams not being navigable, no costly locks will be required to accommodate the trade; while the construction of the dams will be rendered exceedingly cheap by the abundance of excellent materials, and the firm foundations which the rocky valleys afford. The reservoirs that will there be formed will be surrounded by precipitous cliffs, and quite secluded from all public and private

interests. In such positions, the mass of water may be retained, while the great streams need not be resorted to at all; or, if used, used only as the sites of capacious *regulating reservoirs*, corresponding in their functions with the distributing basins of common water-works.

In fact, a critical examination of these records will show, that it is only necessary to render the monthly summer discharge of the principal tributaries uniform, and retain an exceedingly small volume of surplus water—conditions which would involve a very moderate outlay—greatly to improve the navigation during the season of drought.

To supply a large volume of water, with a view to the maintenance of a depth sufficient for the proper movement of the largest class of freighted boats, would certainly require very capacious reservoirs, and an outlay of some six, or, possibly, seven hundred thousand dollars. But merely *to regulate the actual summer discharge*, so as to make it uniform, and supply the additional quantity which would be needed to keep a depth of only four feet on the bar at Wheeling throughout the year, would, in the opinion of the author, involve an outlay little, if any, greater than the cost of two of the locks and dams in actual use on the Monongahela navigation.

TABLE XII.

RECORD OF THE DAILY HEIGHT ON THE WHEELING BAR FOR THE YEAR 1845.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	9	9	12	8½	7	2⅝	6½	2 1/16	2½	5	3¼	4
2	8	8	11	9	8	2½	5½	2⅝	2⅝	4⅝	3¼	4¼
3	7	7	9½	8	7¼	2¼	5½	2⅜	2⅜	4⅝	3½	3 7/16*
4	6½	6½	8	7⅝	8	2½	6½	2⅝	3 1/16	4⅝	4¼	3½*
5	6½	6	7¾	7¼	8¼	2 7/16	8½	2 1/16	3⅓	5	4⅜	3¼*
6	6	5⅝	13	7	7½	2 5/16	9	3	2 1/16	6	7	3½*
7	7	5½	18	6½	7	2¼	8	2⅝	4	6½	7½	3½*
8	7	5½	20	6	7	2 7/16	8	2⅜	4½	5¾	6⅜	7½*
9	7½	5	20	6	7	2 1/16	5⅝	2 7/16	3⅝	6	6 7/16	5*
10	8	5	19	5	6½	2 7/16	6½	2⅝	3¼	6⅝	6½	5*
11	7	5	22	5	6	2 5/16	5½	2 7/16	3½	6⅝	7	5*
12	6	5	24	5	5½	2½	4½	2½	2 1/16	10	7½	8
13	6	5½	22	4½	5⅜	2⅜	4	2 7/16	2⅜	10	8½	7 5/16
14	6	8	20	4⅜	5	2⅝	3¾	2⅜	2⅛	11½	7 7/16	6
15	6	10½	17	4¼	4⅝	3 1/16	3 5/16	2¾	2 5/16	15	7½	5 5/16
16	5	13	15	4⅛	4⅜	3⅛	3¼	2⅝	2¼	13½	7	5⅛
17	5½	14	13	4½	3½	3	3	2 1/16	2 5/16	12	6⅝	4 1/16
18	9	13	11	4 1/16	4	2 1/16	2 1/16	2¾	2¼	10	6½	5¼
19	19	13	11	3⅝	4	2⅝	3¼	2¼	2⅛	7½	5 7/16	6⅜
20	21	11	9½	3⅜	4	3 1/16	3¼	2 5/16	7½	5⅛	6½	
21	17	10	9	3 7/16	3¾	3⅜	3	2⅝	2⅝	6½	5½	5*
22	15	9	8	3½	3½	4	2½	2⅝	3	6	5⅛	5½*
23	14	11	8	3⅜	3	5⅛	2 5/16	2¾	3	5¼	5 7/16	5*
24	11	14	7½	4	3	4⅜	2 5/16	3 1/16	3½	4⅜	5	4½*
25	15	16	8	4½	3½	12	2¾	3⅛	4½	4½	5⅝	4*
26	16	16	7½	4⅛	2 1/16	14	4	3⅛	4⅝	4	4⅜	4*
27	16	15½	7½	4½	2⅝	11	3¾	3	4½	4	3½	3 5/16*
28	13	14	6½	4½	2⅝	8½	3⅜	2¾	4⅝	3⅝	3¾	3*
29	11	—	6½	4	2¾	5⅝	3½	2¾	5⅛	3¾	4⅜	3*
30	10	—	8	5½	2½	7	3	2¾	5½	3¾	4 1/16	3*
31	9½	—	7½	—	2½	—	2 1/16	2 5/16	—	3¾	—	3*
Discharge in each month in cubic feet.	93,843,000,000	77,542,000,000	136,774,000,000	29,672,000,000	29,082,000,000	26,774,000,000	25,075,000,000	11,340,000,000	14,532,000,000	50,557,000,000	33,601,000,000	26,690,000,000
Eq. mo. heights.	$10\frac{59}{100}$	$9\frac{95}{100}$	$13\frac{24}{100}$	$5\frac{45}{100}$	$5\frac{26}{100}$	$5\frac{10}{100}$	$4\frac{87}{100}$	$2\frac{82}{100}$	$3\frac{40}{100}$	$7\frac{84}{100}$	$5\frac{86}{100}$	5

Annual discharge, 555,482,000,000 cu. ft.; equiv. uniform depth, 7.03 ft.

* Closed by ice.

The total drainage of the Ohio, above Wheeling, for the year 1845, was but—

555,482,000,000 cubic feet;

and the average daily discharge—

1,522,000,000 cubic feet.

Comparing these quantities with the corresponding results for 1847, we observe the curious fact, that rather more than twice as much water was shed from the country drained by the tributaries of the Ohio, in the year 1847, as in 1845.

It is possible that an inspection of the observations on the fall of rain for those two years, in the same region, may show that the actual fall was greater in 1847 than in 1845—a fact which would alone explain this result. But it is by no means certain that the year in which there is the greatest number of inches of rain and snow indicated by the gauge, is also that which will exhibit the greatest discharge by the rivers of the country. The volume discharged depends more on the season when the rain falls, and the quantities falling in a given period, than upon the actual annual supply. Much of the winter's rain lies congealed upon the mountains, and at the northern sources of the stream, and suffers but little loss from evaporation, until the first general thaw dissolves the snows, and the whole quantity collected is poured off in a flood; while that which falls in summer showers is evaporated at once, or

absorbed by the dry earth, to be slowly evaporated before it can affect the springs.

A slight change of circumstances affects the annual discharge. The early winter may be too mild to produce heavy snows, and the rain may pass off in floods in December; or it may be so severe as to freeze all the moisture that reaches the earth, so that it will be retained in the hills until the approach of the next spring. If the water which falls runs off in December, it will affect the discharge for the year which closes with December. But if retained in the form of snow, it will be held over, and serve to swell the discharge of the succeeding spring. In fact it will be found that by placing the beginning of the year in July, so as always to include the downfall of winter and spring in the same year, the difference between the measured drainage of two consecutive seasons will be greatly reduced.

The foregoing irregularities may thus be accounted for, to some extent, without assuming corresponding irregularities in the fall of rain. Yet, the difference between the quantities which passed from the upper Ohio to the ocean, in 1845 and 1847 respectively, may really be due, in part, to a difference in the amounts of rain which actually fell in the respective years. The writer has neither library nor meteorological records, at his command, and cannot now properly investigate this branch of his subject.

The quantity of water which flowed down the Ohio in 1845, was sufficient to have maintained a uniform

depth on the bar at Wheeling, throughout the year, of $7\frac{3}{100}$ feet.

The drainage of the whole country, for this year, was equal to $\frac{819}{1000}$ of a foot; or,

$$9\frac{83}{100} \text{ inches.}$$

The greatest monthly drainage was in March, when it amounted to—

$$2\frac{4}{10} \text{ inches:}$$

and the least monthly drainage in August, when it was but—

$$\frac{204}{1000} \text{ of an inch.}$$

In every month of the year 1845, from April to December, including both, one or two periods of low water occurred, requiring the aid of the artificial supply. Indeed, throughout the whole space of eleven years, which the authentic records cover, there is found no period in which the navigation of the Ohio was more precarious than in the year 1845, when it was subject to frequent and total interruptions, both from ice and low water.

To have maintained a depth of five feet in the channel throughout that year, the reservoirs would have been drawn upon *twelve times*, and would have been filled again eleven of those times by the surplus which was wasted during the same month. Even in this year, small as was the quantity which the tributaries furnished, and frequent as were the periods of deficiency, the greatest volume needed to be accumulated in the reservoirs at any time was but 28,744,000,000 cubic

feet. In the months of July, August, and September, there were seventy-nine consecutive days, during which the depth on the Wheeling bar was less than five feet; yet the deficiency for all that period was less than 29,000,000,000 cubic feet—a volume no larger than can be collected in three or four reservoirs, which, on almost any part of the Monongahela or Alleghany, could be formed by dams from thirty-five to forty feet high.

But, as all the objections that can possibly be urged against the construction of high dams on these great rivers may be obviated, as already stated, by resorting to the smaller affluents, it will be the aim of the writer to make a first demonstration of his plan in localities remote from the leading channels of trade, and where there are no important private interests to be consulted.

The only natural lake that would be at all available for this object is the Chatauque, of which the waters flow into the Alleghany, above Warren. But this beautiful basin is itself filled from an area of country too small to contribute any material supply for the purposes here contemplated, and cannot, therefore, be resorted to with much profit.

TABLE XIII.

RECORD OF THE DAILY HEIGHT ON THE WHEELING BAR FOR THE YEAR 1844.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	11	5	7	13	7	7	8	6	5	2 7/8	14	9
2	10	5	8	12	7	9	7	7	5	2 3/8	11	8
3	9	4 1/2	8	11	6	10	6	8	5	4	10	8
4	9	4 1/2	10	10	7	9	6	7	5 3/8	4	10	9
5	8	5	14	10	9	8	8	6	7	3 3/8	12	9
6	8	6	13	9	11	7	9	5 3/8	6	3 3/8	16	9
7	8	7	11	9	9	6 1/8	8	5	5 3/8	3 3/8	15	9
8	7	6 3/8	9	11	8	6	7	4 3/8	4 3/8	3 1/4	13	9
9	7	6	9	12	7 3/8	5 3/8	13	4	4	3 1/4	11	10
10	7	5 3/8	12	12	8	5	10	4	4	3 1/8	10	14
11	6 1/8	5	13	12	7 1/8	4 3/8	7	4	3 3/8	3	8	12
11	5	4 1/8	14	11	7 1/8	4 1/4	6	4	3 1/4	3	7	10
13	6	4 1/8	15	11	7	4 1/8	5	3 3/8	3 1/8	2 3/8	8	9
14	7	4 1/8	16	10	8	4 1/8	5 1/8	4 1/8	3	2 3/8	11	8
15	11	5	17	9	8	5	5	4	2 5/8	2 3/8	14	7
16	10	5	16	8	8	10	4 1/4	3 1/4	2 3/4	2 1/4	12	6
17	9	5	17	7	8	9	4 1/4	3 1/4	2 1/4	2 1/8	10	6
18	9	4 1/8	18	6 1/8	9	7	4	3 1/4	2 1/4	3	9	5 3/8
19	9	4 3/8	19	6	12	6	4 3/8	3	2 1/4	5	9	5 1/4
20	8	4 3/8	17	6	12	5 1/4	5	3	2 1/4	8	8	5
21	8	4 1/4	15	5 1/4	11	6 1/4	5 1/4	3 1/4	2 1/8	10	7	4 1/4
22	7	5	13	5 1/4	11	6	5	3 1/4	2	8	7	4 1/4
23	7	5 1/4	12	5	14	5 1/4	5 1/4	4	1 7/8	7	7	4 1/4
24	8	6	11	4 1/4	13	9	5	4 1/4	1 5/8	6	8	4 1/4
25	14	7	10	4 1/4	11	9	4 1/4	5 1/4	1 3/8	5 1/4	7	5
26	11	6 1/4	9	4	9	8	4	6	1 3/8	5	7	5
27	10	6 1/4	8	4	8	7	4 1/2	5 1/4	1 1/4	5	6	5
28	9	6	8	5	7	8	5 1/2	5	1 1/8	4 1/8	6	7
29	7	6 3/8	8	5 3/8	6 3/8	7 3/8	10	5 1/8	1 1/8	6	6	11
30	7	—	9	7	8	8	9	5	1 1/8	14	6	11
31	6 3/8	—	10	—	7	—	7	5	—	16	—	10
Discharge in each month in cubic feet.	64,936,000,000	28,523,000,000	123,840,000,000	62,753,000,000	70,656,000,000	45,954,000,000	42,628,000,000	25,446,000,000	14,577,000,000	33,361,000,000	79,624,000,000	58,684,000,000
Eq. mo. heights.	$8\frac{50}{100}$	$5\frac{43}{100}$	$12\frac{50}{100}$	$8\frac{32}{100}$	$8\frac{92}{100}$	$7\frac{6}{100}$	$6\frac{62}{100}$	$4\frac{83}{100}$	$3\frac{41}{100}$	$5\frac{68}{100}$	$9\frac{78}{100}$	8

Annual discharge, 650,982,000,000 cu. ft.; equiv. uniform depth, 7.725 ft.

The discharge of the Ohio, calculated from the data offered in the foregoing record, exhibits for the volume of water which flowed past Wheeling in 1844, a season of more than ordinary dryness,

650,982,000,000 cubic feet;

and for the average daily discharge,

1,779,000,000 cubic feet;

and for the uniform height which this quantity would have maintained upon the bar at Wheeling,

$7\frac{725}{1000}$ feet.

The drainage of the country for that year was $\frac{96}{100}$ of a foot, or,

$11\frac{52}{100}$ inches;

which is almost precisely the amount ordinarily assumed by engineers as the supply that may be relied on for canal-feeders, but by no means that which ought to be uniformly anticipated. There is, in fact, scarcely an approach to uniformity in the annual discharge of streams in this climate.

The practical conclusions drawn from the analysis of the record for the year 1844, are also important. During a portion of September, the water fell below 14 inches on Wheeling bar; and, both in August and October, it was down as low as 3 feet, or less. Yet, the irregular discharge for the month of August, was sufficient to have maintained a uniform depth, throughout that month, of $4\frac{83}{100}$ feet; and it would have required no greater accession to the natural supply of the

stream, if this supply had been properly regulated by art, to maintain a uniform depth of 5 feet, than would be afforded by many of the dams actually erected and in use on the navigable rivers of this country.

In the month of September, the water was down as low as 1½ feet; yet a single dam on the Alleghany, and one other on the Monongahela—neither being larger than those already built by the Monongahela Navigation Company—properly constructed, and supplied with appropriate gates, would have been all-sufficient to have regulated the actual discharge, and maintained a uniform depth of 4 feet throughout that month.

It may be stated as a general fact, which can be fully demonstrated by these measurements, that two dams, no higher than the Blue Mountain dam on the Schuylkill navigation—one of which should arrest the waters of the Alleghany, and the other those of the Monongahela—could be safely relied on for permanently maintaining a depth of 4 feet, and clearing the river effectually of obstruction from ice, so that the navigation for boats of that draft need be subject to no future interruptions. A depth of 4 feet will permit the best class of Pittsburg packets to run all the year; and this result, in the opinion of the writer, could have been easily obtained in 1844 for an expenditure not exceeding three hundred thousand dollars.

TABLE XIV.

RECORD OF THE DAILY HEIGHT ON THE WHEELING BAR FOR THE YEAR 1843.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	5	13	7	17	18	10	4	$2\frac{1}{4}$	$1\frac{7}{8}$	7	$7\frac{3}{8}$	7
2	6	14	7	20	17	9	4	$2\frac{1}{4}$	$1\frac{7}{8}$	7	7	7
3	6	13	6	18	17	8	$3\frac{7}{8}$	$2\frac{1}{4}$	$1\frac{7}{8}$	5	$6\frac{3}{8}$	$6\frac{3}{8}$
4	$6\frac{3}{8}$	11	6	17	16	8	$3\frac{3}{4}$	2	$1\frac{7}{8}$	$4\frac{3}{8}$	6	$6\frac{3}{8}$
5	$6\frac{3}{8}$	10	5	16	14	12	$3\frac{3}{8}$	2	$1\frac{3}{4}$	4	6	6
6	7	9	5	15	12	17	$3\frac{1}{4}$	2	2	4	$5\frac{3}{8}$	$5\frac{3}{8}$
7	7	8	$4\frac{3}{8}$	17	10	19	$3\frac{1}{4}$	2	2	4	$5\frac{3}{8}$	$5\frac{3}{8}$
8	8	7	$4\frac{3}{8}$	17	8	16	$3\frac{1}{4}$	2	$2\frac{1}{8}$	4	5	$5\frac{3}{8}$
9	9	7	$4\frac{3}{8}$	18	8	13	3	2	3	4	5	5
10	10	6	8	20	8	11	$2\frac{7}{8}$	2	5	7	5	5
11	12	6	10	20	8	12	$2\frac{3}{4}$	2	7	10	6	5
12	20	6	13	17	9	16	$2\frac{3}{8}$	$1\frac{7}{8}$	6	9	9	$4\frac{3}{8}$
13	25	$6\frac{1}{4}$	13	15	10	16	$2\frac{3}{8}$	$1\frac{7}{8}$	7	8	12	5
14	26	7	13	15	10	14	$2\frac{3}{8}$	$1\frac{7}{8}$	9	8	18	8
15	20	7	12	18	9	12	9	$1\frac{7}{8}$	9	7	15	7
16	17	7	10	18	10	12	7	$1\frac{7}{8}$	9	$6\frac{1}{4}$	12	8
17	12	7	9	22	8	10	$5\frac{1}{8}$	$1\frac{3}{4}$	20	$6\frac{3}{8}$	10	10
18	11	7	$7\frac{1}{2}$	25	7	12	$4\frac{3}{8}$	$1\frac{3}{4}$	15	$6\frac{3}{8}$	9	16
19	10	7	7	27	6	13	$4\frac{3}{8}$	$1\frac{3}{4}$	10	$6\frac{3}{8}$	10	20
20	9	8	$6\frac{3}{8}$	26	$5\frac{3}{8}$	11	4	$1\frac{3}{4}$	9	7	12	18
21	8	8	6	24	$5\frac{3}{8}$	9	$3\frac{7}{8}$	$1\frac{3}{4}$	8	8	14	16
22	8	11	$5\frac{3}{8}$	22	5	8	$3\frac{3}{8}$	$1\frac{7}{8}$	7	8	15	12
23	8	10	5	18	5	7	3	$1\frac{7}{8}$	6	9	15	12
24	10	9	5	20	$4\frac{3}{8}$	6	3	$1\frac{3}{4}$	5	9	14	16
25	10	9	$4\frac{3}{8}$	21	$4\frac{3}{8}$	$5\frac{3}{8}$	3	$1\frac{3}{4}$	$4\frac{3}{8}$	8	12	18
26	9	8	$4\frac{3}{8}$	20	$4\frac{3}{8}$	5	$2\frac{3}{8}$	$1\frac{3}{4}$	$4\frac{3}{8}$	7	11	17
27	9	8	$4\frac{1}{4}$	19	$4\frac{3}{8}$	5	$2\frac{3}{8}$	$1\frac{3}{4}$	$4\frac{3}{8}$	7	10	15
28	8	8	6	17	$5\frac{3}{8}$	$4\frac{3}{8}$	$2\frac{1}{4}$	$1\frac{3}{4}$	6	7	9	14
29	10		12	19	7	4	$2\frac{1}{4}$	$1\frac{3}{4}$	10	$7\frac{3}{8}$	8	13
30	11		18	19	9	4	$2\frac{1}{4}$	$1\frac{3}{4}$	9	$7\frac{3}{8}$	7	13
31	11		17		11		$2\frac{1}{8}$	$1\frac{7}{8}$		$7\frac{3}{8}$		12
Discharge in each month in cubic feet.	109,193,000,000	60,568,000,000	65,215,000,000	251,449,000,000	78,393,000,000	94,841,000,000	17,815,000,000	6,684,000,000	47,471,000,000	46,063,000,000	82,890,000,000	100,800,000,000
Eq. mo. heights.	$11\frac{69}{100}$	$8\frac{65}{100}$	$8\frac{50}{100}$	$19\frac{40}{100}$	$9\frac{59}{100}$	$10\frac{87}{100}$	$3\frac{80}{100}$	$1\frac{90}{100}$	$7\frac{80}{100}$	$6\frac{93}{100}$	10	$11\frac{5}{100}$

Annual discharge, 961,382,000,000 cu. ft.; equiv. uniform depth, 9.73.

It appears from the foregoing record that the volume of water which flowed down the Ohio at Wheeling, in 1843, amounted to—

961,382,000,000 cubic feet;

and that the equivalent average daily supply is—

2,634,000,000 cubic feet.

This quantity is sufficient to maintain a uniform height throughout the year, upon the Wheeling bar, of—

$9\frac{73}{100}$ feet.

The total drainage for that year was $1\frac{417}{1000}$ feet, or—

17 inches.

The greatest monthly drainage was in April, when it amounted to—

$4\frac{44}{100}$ inches;

and the least monthly drainage in August, when it amounted only to—

$\frac{12}{100}$ of an inch.

If we look over the values of the monthly drainage for the six years which have been analyzed, it will be observed that the volume of water which passed down the Ohio in April, 1843, was greater than the amount shed during any other month in all that period; while the amount discharged in August, 1843, was less than the discharge of any other month in the same space of six years.

The results of this year's analysis show, also, that the navigation might have been very easily maintained at a height of more than five feet, by two or three reservoirs of very moderate capacity.

It is not necessary to multiply observations bearing on a fact already sufficiently explained. The capability of the upper branches of the Ohio to furnish adequate reservoir sites will be alluded to in the sequel. It is sufficient to say here, that the navigation may be permanently upheld, free from all obstruction from ice or drought, by the construction of a few dams across the tributary streams, and providing those dams with locks for the convenience of the local trade, and with appropriate pipes and valves for drawing off the water held in reserve, as it is needed.

The same dams that will serve to supply the channel with water in the summer months, and sweep away the ice which collects during the low water of winter, will enable us also to shut off the water entirely, so as to lay bare the bars when it is desirable to do so, to remove obstructions, and, as we shall presently see, even to hold back the floods, when they threaten to desolate the valley below. In fact, we can exercise as complete control over this great river as we possess over the discharge of a hydrant.

These views, when originally promulgated by the author, were almost universally regarded as Quixotic. But it has been a source of gratification to him to find that they have not failed to win their way into the

public confidence, and are now very generally accepted by the profession.

In collecting the foregoing results, we obtain the following averages for a period of six years:—

The total discharge of the Ohio in—

1843	was	961,382,000,000	cubic feet.
1844	"	650,982,000,000	" "
1845	"	555,482,000,000	" "
1846	"	879,119,000,000	" "
1847	"	1,142,258,000,000	" "
1848	"	822,719,000,000	" "
Total for six years		5,011,942,000,000	" "
Annual average		835,323,000,000	" "
Daily average, for six years		2,287,000,000	cubic feet.

By applying the formula, or Table VIII., we find that this quantity is just sufficient to have maintained the river at a uniform height of $8\frac{94}{100}$ feet during this entire period of six years.

The annual drainage, as we have seen, in—

1843	was	17	inches.
1844	"	$11\frac{52}{100}$	"
1845	"	$9\frac{83}{100}$	"
1846	"	$15\frac{56}{100}$	"
1847	"	$20\frac{20}{100}$	"
1848	"	$14\frac{57}{100}$	"
Total drainage for six years		$88\frac{67}{100}$	"
Annual average		$14\frac{778}{1000}$	inches.

The average annual fall of rain at the head of the Ohio is about 36 inches. The discharge is, therefore, about 40 per cent. of the total fall; showing that 60 per cent. of all the rain and snow that come to the

earth in this latitude is carried back to the clouds in vapor, and never reaches the ocean.

There are [illegible] meteorological records which would enable us to state the average annual fall of rain in the basin of country which is drained by the upper Ohio more accurately than it is here given for these six years; but the engagements and present position of the writer have not permitted him to pursue that branch of his subject minutely.

The average result here stated, however—40 per cent. for the drainage, and 60 per cent. for the evaporation and vegetable consumption—will be found to be very nearly the proportions in which the total fall of rain, in this climate, is actually divided.

Since the publication of the first edition of this paper in the *Transactions* of the Smithsonian Institution, the attention of the James River and Kanawha Company has been directed to the investigation of the practicability of feeding the summit level of their proposed canal across the Alleghany Mountains, in Virginia, by the formation of capacious reservoirs on the minute tributaries west of the summit.

The result of this investigation, which has fully established the practicability of a very unwise measure, possesses much scientific interest. The downfall of rain on the Alleghany Mountains near the head-waters of Anthony's Creek, a tributary of the Greenbrier River, which flows into the great Kanawha, a tributary of the Ohio, was found to be, by the gauge, for the past year, 34.23 inches; and the average fall for the last five years, 36.386 inches.

The discharge of the creek, of which the area of drainage was carefully surveyed, was ascertained, by daily measurements for the last year, to amount to 70 per cent. of the downfall for the year, and 65½ per cent. of the average fall for five consecutive years.

These observations, which are exhibited in the Report of Mr. E. Lorraine, civil engineer, addressed to Mr. W. Gwynn, the chief-engineer of the Company, show conclusively that the drainage of the upper tributaries of the great rivers, which have their sources in mountainous regions, greatly exceeds the average drainage of the country, measured at lower points. The explanation of this difference is most obvious; and accords precisely with the ground upon which it has been contended by the writer that the proportion of the drainage to the evaporation in the western prairies is increased by the cultivation of the soil. The water is hastened off, in the one case by the steep slopes of the mountain sides, and in the other by artificial drains, into the streams below, instead of resting on the flat soil until it is either slowly absorbed by the earth, or slowly evaporated by the sun.

OF THE FLOODS OF THE OHIO.

The records exhibited in the preceding pages, and the volumes of water discharged in periods of twenty-four hours, when the river is at given heights, shown in Table VIII., are useful in another application. They teach us the important fact, that the great floods of this

river may be so controlled as to be deprived of their destructive power, and forced, by the hand of man, to glide harmlessly to their place in the ocean.

A flood in a great river, like the Ohio, is but A WAVE, spreading along a limited portion of its course. The banks of the stream are only overflowed by water from the same tributary, for a very short distance at the same time, and the channel of the river is never filled simultaneously from its source to its mouth. When there is a great rise at Pittsburg, there is no perceptible rise, produced by water from the Alleghany and Monongahela, at Louisville; and when the flood originating at Pittsburg has reached Louisville, the water has always subsided again at Pittsburg.

A great flood in the upper Ohio rarely continues at its extreme height more than ten or twelve hours; and but a single instance can be found in the records of the last eleven years, of a rise which continued at a greater height than 25 feet at Wheeling, longer than four days. When the river is at its highest mark at any point, as it usually remains at that level but the fraction of a day, it is rising 100 miles below, and falling 100 miles above; it has quite a moderate rise 200 miles below; and has receded again, within moderate bounds, 200 miles above. From these extremes it rises towards the point which, for the moment, is the top of the swell, forming *a wave*, as is represented in Plate XI., Fig. 2. (See page 233.)

This figure is not designed to show the absolute form of the wave, the height of which is due to the difference

between the inclination of the surface during the flood, and in the ordinary regimen of the stream; and varies, from hour to hour, as the supply becomes greater or less than, or just equal to, the discharge. The slope of the river is not represented in the cut, and the height of the wave is greatly exaggerated. In fact, the surface descends from A to C, although C is, compared with the summer level of the stream, higher than A.

At the point A the river may have fallen to 25 feet, and at the point B it may have risen to 25 feet above low water; while at C, the centre of the swell, it might stand—as during the great flood of 1832, at Wheeling—45 feet above low water. On that remarkable occasion the flood rose 13 feet in the twenty-four hours preceding the attainment of its greatest height; and, as we shall presently see that the apex of the curve did not move more than 61 miles per diem, this must have been but little more than a common spring flood at any point 100 miles distant from the top of the wave.

Now, it is not the height at A and B, which the river reaches 100 miles above or below the crest of the curve, that causes the destruction of life and property. It is the top of the wave only, which is sweeping through the valley, buoying up and bearing off every floating object above the line of harmless rise, A B, that is injurious to the works of men.

To control a flood, and render it harmless, we must retain in reservoirs the volume of water which produces that portion of this wave above the line A B, and fills

two-thirds of the rectangle, *a*A, *b*B. A rise of 25 feet is a flood which, at Wheeling, is shown by experience to cause but little damage. The difference, therefore, between the discharge of the river when at 25 feet, and the actual discharge for whatever period the height rules above 25 feet, is the volume of water to be retained to render the flood entirely harmless.

To make a practical application of the facts, we will take the flood of March, 1841, which, because of its long continuance, would have been the most difficult to control of all the freshets that have occurred within the last eleven years, although there have been instances when the height of the water has been greater for a brief period.

The records (see Note N), and Table VIII., furnish the following data:—

March	24,	height,	31	feet,	discharge,	17,972,000,000 cubic feet.
"	25,	"	32	"	"	18,760,000,000 " "
"	26,	"	30	"	"	17,088,000,000 " "
"	27,	"	28	"	"	15,322,000,000 " "
"	28,	"	30	"	"	17,088,000,000 " "
"	29,	"	34	"	"	20,624,000,000 " "
"	30,	"	33	"	"	19,700,000,000 " "
"	31,	"	30	"	"	17,088,000,000 " "
April	1,	"	28	"	"	15,322,000,000 " "
Total discharge during these nine days of high water,						158,964,000,000 cubic feet.

This is the entire volume of water which passed down the river while the height of its surface was more than 25 feet upon the Wheeling bar. But to have kept this flood down to 25 feet all that time, we need only

to have retained the excess of the discharge over and above the quantity which would have been vented during the same period, at a 25 feet stage.

The diurnal discharge of the Ohio, when there is 25 feet in the channel, is, by Table VIII., 12,752,000,000 cubic feet; and the total discharge for these nine days would then have been, at that depth, 114,768,000,000 cubic feet. The difference between this quantity and the actual discharge is 44,196,000,000 cubic feet; and this is the volume which the reservoirs must be capable of holding, to enable us to control such a flood as that of 1841, so as to render it harmless at Wheeling.

This volume is just equal to the quantity which the river would discharge in 50 days, when there is a depth of 5 feet in the channel.

If, then, we construct reservoirs upon the Alleghany and Monongahela, or their tributaries, of sufficient capacity to supply the actual discharge for fifty days, at a height of 5 feet, these reservoirs will contain all the water that it is necessary to hold back to protect the upper portions of the valley from the injurious effects of ordinary floods. A reservoir adequate to this object would be four miles square, and very nearly 100 feet deep.

A single dam, no higher than some of those constructed for the canals of this country, may be built on the Alleghany, which will form a lake nearly thirty miles long, with numerous branches, also many miles in extent, and capable of supplying nearly the whole volume of water required for the navigation from that

direction, while greatly restraining the floods which proceed from that arm of the Ohio. Equally available sites can be found on the great tributaries of the Monongahela, where reservoirs can be formed without injury to valuable property, competent to supply the deficiency in periods of drought, and capable of controlling the floods in that direction also, when the supply of water is there in excess.

To exercise complete control over all injurious floods will involve a greater outlay than will be required for the effectual improvement of the navigation; but even this can be accomplished by works which will also secure to the navigation a permanent depth of *six feet*, for about the cost of maintaining a ship of the line on a three years' cruise.

The surface-velocity of the central current of the Ohio River, at Wheeling, when the average depth in the channel is 35 feet, is very nearly five miles an hour, and the mean velocity of the whole mass of water, four miles an hour. The total movement of the stream, after the river is filled, is, therefore, very nearly 100 miles a day; and the velocity of a float in the centre of the channel, about 120 miles a day.

These are the results of actual measurements. Yet, though such is the rate of motion of the stream, it can be shown that the movement of the top of the *flood-wave* is a great deal less than this.

The greatest flood of which we have either recorded or traditionary account on the Ohio, is the famous rise of February, 1832, when the river attained a height of

31 feet at Pittsburg, 45 feet at Wheeling, and 63 feet at Cincinnati, above its summer surface.

This flood reached its highest mark from place to place along the river, at the following dates :—

Pittsburg . . .	February 10			
Wheeling . . .	" 11 . . .	(evening) . . .	88	miles.
Marietta . . .	" 13 . . .	(noon)	176	"
Maysville . . .	" 16 . . .	(night)	405	"
Cincinnati . . .	" 17 . . .	(midnight) . .	460	"
Louisville . . .	" 21 . . .	(morning) . . .	613	"

These dates are chiefly taken from the newspapers of that day—the papers of each city generally recording the time when the water ceased to threaten their respective towns with increasing calamities. From these facts, it appears that that remarkable wave travelled from Pittsburg to Cincinnati—a distance computed at 460 miles—in 7½ days; or at the rate of 61 miles a day, or 2½ miles an hour. The rate of the progress of this flood was, therefore, but a fraction more than half as great as the surface-velocity of the river in the channel at Wheeling; and but two-thirds of the velocity of the whole mass of water, after it had attained the height of 35 feet.

We do not know, from actual measurement, the precise velocity of the central surface thread of the Ohio at the top of this flood; but, computing it from velocities carefully observed up to 31½ feet, it must have been about six miles an hour, or more than twice as great as the actual progress of the flood itself.

This apparent paradox is susceptible of easy and satisfactory explanation. The flood coming from the

mountains finds the channel nearly empty as it approaches. The water which rolls past any given point has, therefore, a double duty to perform; first, to fill the channel below, and then to supply the volume which the channel below discharges. The wave is partly spent in filling the empty channel, and is retarded while being replenished from above.

The same circumstance which explains the retardation of the flood-wave, accounts also for another fact observable in the progress of all great freshets—that, while the water is rising, the *drift* leaves the channel, and tends towards the shores; and as the surface falls it recedes from the shores, and seeks the thread of the channel. The swiftest water is near the centre of the river, where there is always the least resistance. The empty stream below is, therefore, first supplied by the central fillet. The foremost water comes down along the centre and at the surface, and flows from the centre towards the shores, to fill up the vacant space. The river, while on the rise, is consequently higher at the centre than at the borders; and the drift descends on the surface, following the lateral current towards the banks.

But, as the water falls, the effect is reversed. The supply first fails above, while the draft still continues from below, and is most rapid at the centre, where there is still the least resistance. The void occasioned by the draft is consequently first produced in the centre, and the water flows in from the shores to supply the void. The drift again obeys the lateral current until it reaches

the channel, which, by this excess of the central draft, is depressed below the surface at the shores. The drift floats down the slopes of this depression, and has no power to ascend the plane on either side to regain the shores.

These considerations explain the difficulty, well known to pilots on this river, of keeping the channel on a rising stream. The water being then highest in the centre, the boat is continually drawn towards the banks; while every raftsman knows that it requires no skill to float down the current when the flood is subsiding. This fact is well expressed in the language of an old flat-boat man, who assured the writer that "he had floated twenty-four hours on a falling river, without once wetting a sweep."

Although, in this paper, the computations have only been made with a view to the reduction of the extreme height of the flood-wave, so as to show that it is quite practicable to render it harmless, there are many interests in society which would be promoted by a further extension of the system, and an ultimate approach towards an equalization of the daily discharge. It is quite reasonable to suppose that, in course of time, all the waters of all the navigable rivers will be required to supply the wants of man and his commerce. Reservoirs may eventually be made, of sufficient capacity to hold *all* the annual excess, and make the daily flow almost entirely uniform. The banks of the Ohio and Mississippi, now broken by the current and lined with fallen trees, ready to be swept by the next freshet into

the channel, there to form dangerous snags, may yet, in the course of a very few years, be cultivated and adorned down to the water's edge. In the opinion of the writer, the grass will hereafter grow luxuriantly along the caving banks; all material fluctuations of the waters will be prevented, and the level of the river's surface will become nearly stationary. Grounds, which are now frequently inundated and valueless, will be tilled and subdued; the sandbars will be permanently covered, and, under a uniform regimen of the stream, will probably cease to be produced. The channels will become stationary. The wharves will be built as the wharves on tide-water, with little, if any, reference to the fluctuations of the surface. The lower streets of all the river towns, no longer exposed to inundations, will acquire new value. The turbid waters will be arrested in the upper pools, and the Ohio first, and ultimately the Missouri and Mississippi, will be made to flow forever with a constant, deep, and limpid stream. The ice will be swept off as it forms, and neither cold nor droughts will longer be suffered injuriously to affect the navigation. The ocean steamers will not then be confined to tide-waters, but will be able safely to ascend the living streams to seaports on their borders, and the extent of the inland navigation will be limited only by the limit to the water which is supplied by the atmosphere.

All this may be accomplished on the Ohio *for about the cost of three or four ships of the line.* The great and only difficulty is, so far to overcome the cold incredulity

of the public as to obtain from Congress a sufficient appropriation for the completion of the first two reservoirs. This once effected, and a single practical demonstration made, it will perhaps be as difficult to convince the future engineer that a thing so clear and palpable could ever have been doubted, as it at first was to remove the doubts.

As an effort of art, the work of controlling the floods of the great rivers of the Mississippi valley, will never compare with the labors of men in other departments of practical science. More money has been laid out on three miles of railroad than would be needed to maintain the waters of the Ohio within two feet of a uniform height throughout the year; to add a length of several hundred miles to the river navigation of the country, and render more than two thousand miles of precarious navigation permanent and certain. The same reservoir that keeps back the excess of water from the tributary, keeps it back also from the recipient stream; the same supply that maintains the navigation of the tributary, also improves that of the recipient; and the same reservoir that serves to maintain the navigation of both tributary and recipient, serves, of necessity, to protect both from overflow.

These things will be effected, not by main force, but by skill. The rain-gauge will indicate the approaching danger from the summits of the distant mountains; the telegraph will announce the fact at the flood-gates, and the whole may thus be controlled by the previsions of science. In fact, the contemplated effect can be produced

by a few dams in the mountain gorges, and the constant attention of some twenty men.

OF THE IMPROVEMENT OF THE OHIO.

It has become fashionable to depreciate the importance of river navigation as a thing shortly to give way to the great improvements of the age—the railroad and locomotive. But if we reflect that the cost of transporting a barrel of flour from Pittsburg to New Orleans, 2,050 miles, by steamboats, is now often but 50 cents, while the lowest price at which that article can be conveyed by railroads, with any profit, is three cents per ton per mile, or at the rate of $6 per barrel from Pittsburg to New Orleans, we shall better appreciate the importance of the Ohio and Mississippi Rivers to the agricultural and commercial interests of the country.

The present charge for a cabin passenger on the same route, with all the comforts of a good boat, is but $15, for a distance of more than 2,000 miles—and that sum covers his living by the way. The corresponding railroad charge would be from $60 to $80, and the traveller would pay his board on the journey.

The discussion of this subject is quite foreign to the object of the present paper; yet we ought never to forget, when considering the value of the western rivers, that the great cities of Pittsburg, Cincinnati, Louisville, St. Louis, and New Orleans, and scores of less note, all owe their origin, growth, and present prosperity to the river trade. And, until emporiums of equal

mark are built up and maintained by some artificial cause, we have no right to despise the channels that have created the wealth and commercial activity that is concentrated in these. Yet these great cities, prosperous as they are, and rapid as has been their growth, are but isolated though prominent evidences of the general vigor and prosperity of the vast region watered by the great rivers of the West.

The Mississippi valley, with all its depth of soil, and forests of timber and mineral riches, would be a comparative waste, if deprived of the great rivers which penetrate by their branches all its recesses, facilitate its domestic exchanges, and bear all its immense products to the ocean.

In truth, the internal navigation of the country must always be regarded as the arterial circulation of its wealth and commerce; and whatever will improve that navigation deserves the care and patronage of the people, and of those to whom the people confide the protection of their interests.

It has been estimated by Col. Long that the western rivers afford a development of 16,674 miles of steamboat navigation;* while the commerce of these rivers, for the year 1843, according to the estimate submitted to the Senate by Mr. Barrow, possessed a value of more than $220,000,000.†

The navigation of nearly all the streams bearing this

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* Report of the Commissioner of Patents, of December 30, 1848.

† Report of the Committee of Commerce (Senate), February 9, 1843.

vast and rapidly-increasing commerce is interrupted during *more than one-third of the year* by the want of water, or by ice, which accumulates to an injurious extent because of the want of water. This interruption is equivalent in its effects to an annual tax upon the industry of the country equal to one-third the yearly expense of maintaining all the steamboats that are subject to the detention, together with the value of the delay upon all the property that is exposed and detained, and that of the deterioration and early destruction of all the boats that are compelled to run when there is too little water to float them safely.

The number of boats navigating the western rivers is, probably, at this time, not less than 1,000; and it is estimated, partly from accurate official data, and partly from conjectural data based upon official returns, that the total loss from wrecks of steamboats on these waters, for the year 1848 alone, amounted to $2,000,000.

There are no data for determining the loss consequent upon the detention of the boats; but, as the delay falls chiefly upon the largest steamers, which are always first arrested, the loss must greatly exceed the actual cost of maintaining one-third of all the boats in use on the western rivers. But if this item be only equal to the cost of maintaining and running 750 boats one-third of the year, or 250 boats of average value the whole year, it will amount to not less than $3,000,000 per annum, over and above the loss now sustained on the property conveyed, and that on the commerce which cannot be conveyed.

By upholding the draft in the channel, the cost of transportation—which now fluctuates between 8 cents and $1 75 per hundred pounds from Pittsburg to Cincinnati—could be maintained, with profit to the carrier, at about the lowest present charge, and the whole business of the valley would experience a corresponding increase consequent on the reduction of the cost of freight. A vastly increased tonnage would necessarily be conveyed at greatly reduced rates. The business of the transporter would become more certain and more stable; lines would be established to act with regularity and dispatch, and every department of agriculture and commerce, through all the wide valley, would feel the effect of an increase of speed, certainty of delivery, and reduction of the cost of conveyance.

It is scarcely to be doubted that the maintenance of a depth of 5 feet in the Ohio alone, at all seasons, would save the country from an *annual* tax upon its present business, of five millions of dollars, or about eight times the sum necessary to produce the saving.

The value and importance of this navigation, and that of the growing interests dependent upon it, demand an improvement worthy of this government, and worthy the character of a river, navigable in good water a distance of 1,200 miles, and bearing by far the greater portion of an annual commerce already valued at $220,000,000; and no improvement would be worthy of this trade and this position, that will not permit the largest of the New Orleans steamers to ascend the Ohio,

without fear of impediment at all seasons, to Cincinnati and Pittsburg. (See note L.)

All the efforts which have yet been made to improve the great rivers of this country have proceeded upon a plan of gaining depth without an increase of water. There is, however, no better extensive inland navigation in the world, than that afforded by the natural bosom of the Ohio when well supplied with water; and the navigation never fails but when the water fails. The simple remedy, therefore, is to supply the deficiency which produces the evil. (See note M.)

If an engineer had prepared a plan of improvement, contemplating the excavation of *a canal as large as the Ohio*—a thousand miles long, a thousand feet wide, and seven feet deep—and the excavation of reservoirs capacious enough to supply it with water, it would be easy to demonstrate that such a work is feasible, and that the cost might not be greater than the actual value of the river which now connects the seaboard cities with the Mississippi, and floats the commerce of ten or twelve of the States of this Union. The practicability of such a canal could be easily demonstrated, for it involves plans precisely analogous to those of works that have been already executed. Such an enterprise, to use the stereotyped expression of the day, might even be considered worthy of the destinies of the American people, and in accordance with the spirit of the age in which we live.

But the writer has no such magnificent effort to propose—no achievement, even, to compare with the great

works already accomplished by the private enterprise of the country.

It is not proposed to dig a canal, or to form a reservoir. Nature has already prepared the Ohio River, and excavated for it a channel, capacious enough for the largest steamers. Nature has adjusted its bed so admirably, that no locks are needed to overcome its fall; no dams to break its current; no aqueducts to carry it over valleys; no engines to provide it with water, or labor to excavate the lakes which are needed to hold a reserve supply.

The canal is dug, and the lakes are excavated, and the water is abundantly supplied from the clouds. All that is left for the ingenuity and enterprise of man to accomplish, to perfect the navigation, is to build a few stone walls across some of the tributary streams, and hold back a small portion of the surplus water in the lakes that are there already formed, and then provide common sluice-gates to emit that water into the channel when it is needed.

This is all that is necessary for the "spirit" of this and future ages to accomplish, to obtain a perennial and unbroken navigation of nearly 1,000 miles along the Ohio, and many hundred miles along its tributary valleys.

The observations which have been recorded in the foregoing pages will serve to teach us how to proceed in thus improving the navigation, cheaply and permanently, to any practicable extent.

These observations show that, to supply all the water necessary to produce a depth of 2½ feet on the bar at

Wheeling—supposing that the natural supply had failed for a brief period entirely—would require a reservoir capable of furnishing 310,000,000 cubic feet per diem. But looking over the records of the last eleven years, we meet with but one season—that of 1838—when a depth of less than 2½ feet continued for a longer period than 65 days. That was truly a remarkable year—well remembered by every engineer then occupied with works in any manner depending on the supply of rivers. (See Record, note N.)

Taking that season as a guide, we find that to have made up the deficiency of the natural flow of the Ohio, and furnish the excess needed to maintain the depth at 2½ feet, would have required an average augmentation of the natural daily discharge of the stream of 100,000,000 cubic feet, or a total supply, for the 65 days, of 6,500,000,000 cubic feet.

Now, if we construct a dam across the Alleghany River, near Franklin, no higher than one of those on the Lehigh—58 feet—and provide it with a lock for the accommodation of the upper trade, as is usual at the dams across all navigable rivers, we shall observe by the fall of the Alleghany, exhibited in the profile, Plate XII, that this dam will create a reservoir about 25 miles in length, having a depth of 58 feet at one extreme, and reduced to the ordinary depth of the river at the other. But it would do more. It would set back the water many miles up numerous tributary streams which empty into the Alleghany along these 25 miles, and up all the ravines and lateral branches of these tributary streams.

Now, there are many artificial pools on the navigable rivers of this country, from 15 to 20 miles in length. The dam near the grand rapids on the Wabash has formed a pond 17 miles long. The dam at the Horseshoe Bend, on Kentucky River, has created one 27 miles long, and that at Cedar Ripple, on the same stream, has produced a pool of 23 miles. Dams of greater height have been built, and lakes of greater length have been created, on many of the rivers of this country, than will be required by the improvement here proposed; though no doubt it will be found to be good economy to construct higher dams and locks of greater lift, and form reservoirs of greater capacity, in carrying out this system to its full extent, than have yet been demanded by existing works. This course may, and probably will, be dictated by true economy; but it is not at all necessary to success, nor intended to be recommended in the first steps.

The valley of the upper Alleghany is, from hill to hill, about one-third of a mile in width. A reservoir, 25 miles in length, would, therefore, cover an area of some 8 or 9 square miles along the principal valley, and much more than that in its lateral branches. Such a dam as is here spoken of—from 55 to 60 feet in height—would probably form a lake covering from 16 to 18 square miles, with an average depth of near 30 feet, and containing more than 12,000,000,000 cubic feet of water. This is nearly double the quantity which was ascertained above to have been requisite to supply a depth of 2½ feet during the whole of the

summer of 1838, the season of greatest drought ever known west of the Alleghany range.

Now, we have already seen that the whole volume of water constituting the injurious portion of the flood of 1841 could have been retained in reservoirs capable of holding 44,000,000,000 cubic feet. It follows, then, that we should need but four dams, such as are here described, less than 60 feet high, to secure the valley of the upper Ohio against all destructive floods; and these same dams, as already shown, would be capable of supplying the navigation with sufficient water for boats of 5 feet draft during a period of 60 days, if the natural discharge should fail altogether.

But, though the Ohio never ceases entirely to send water to the ocean, it will be seen, by reference to note N, that, during the memorable drought of 1838, there was a period of 120 consecutive days when the depth on the bar at Wheeling was less than 5 feet. The actual average daily discharge during these 120 days, computed by the formula given in this paper, was about 220,000,000 cubic feet. The daily discharge, when there is 5 feet on the bar, has been found to be 864,000,000 cubic feet. The difference between these quantities is 644,000,000, which is the volume that should have been furnished daily for 120 days, in 1838, to have secured a depth of 5 feet throughout that year.

Reservoirs capable of furnishing this volume must possess a capacity of 77,000,000,000 cubic feet. But this was a period of unexampled suffering from drought; and an application of the facts furnished by the tables

and records in these pages shows that a supply which would have been sufficient to secure a depth of 5 feet in 1838, would have secured full *six feet* in any ordinary season.

We shall then require three or four high dams upon the Alleghany and Monongahela, or an equivalent number upon other tributaries of the Ohio, to insure, with this single known exception, a perpetual navigation for boats of 5 feet draft.

It is not appropriate in this place to enter into any detailed estimate of the cost, or description of the mode of constructing, such dams. It may be said, however, that they should be formed of massive masonry, set in hydraulic cement, and built more with reference to the part they are to perform in advancing the commercial prosperity of the country, than with a view to stinted economy. Yet, formed as monuments of the art and enterprise of the age, it is not probable that the cost of each dam, with its lock, valves, syphons, and appurtenances, will exceed $200,000 or $250,000.

It has been the duty of the writer, at former periods, to conduct surveys along a considerable portion of the upper Alleghany, and the whole of the Great Kanawha, and to become familiar with the character of the Monongahela as far as it is susceptible of improvement. Aided by this personal knowledge, and the facts acquired in the present investigation, he hazards the opinion that less than a million and a quarter of dollars will suffice to supply the Ohio with a depth sufficient for boats of 5 feet draft; to carry an open and per-

manent river navigation up the Alleghany to Franklin, and a slack-water navigation, during three-fourths of the year, from Franklin to the line of the Erie Railroad, in New York; improve the navigation of the Monongahela into Virginia, and extend that of the Kanawha 70 or 80 miles above Point Pleasant—supplying water-powers of unrivalled capacity and permanence, on numerous lines of steamboat navigation, and curbing most essentially the destructive power of the floods.

Viewing the insignificant cost for which about 1,400 miles of river navigation may thus be rendered permanently available—without reference to the incidental advantages that will flow from the work—it may well be doubted whether there is, in the whole circle of contemplated public improvements, a projected enterprise which more seriously demands the care and consideration of those who are charged with the protection of the public interests.

The difficulty which the mind first encounters in contemplating this proposition arises from the apparent immensity of the mass of waters to be dealt with. But this is only a speculation. The quantity has been measured, and found to be easily attainable and perfectly manageable.

The total discharge of the Ohio, in ordinary low water, is but 6,000,000 cubic feet per hour. A pipe no larger than one of those used for conveying the water of the Croton Water-works, or three feet in diameter—will discharge very nearly 1,000,000 cubic feet per hour under a head of 60 feet. Six such pipes, then, placed

in a dam only 60 feet high, and provided with proper valves, would emit water enough to double the quantity flowing down the Ohio at its usual summer stage. And if there were three such dams on different streams, and 12 pipes in each, and one man to superintend each dam, and obey the telegraphic signal to open or close the valves—or an equipment equal to three dams no higher than have been already built in this country, and 36 pipes equal in diameter to the mains in Broadway, and three men to manage the whole—the quantity of water could be increased sixfold, and the navigation could be maintained above 5 feet during all ordinary droughts. At the same time, such is, happily, the form of many of the western valleys, that dams of double this height can be often erected without injury to any appreciable amount of property, improved or susceptible of improvement.

WATER-POWER.

The reservoirs which it is proposed to form primarily for the improvement of the navigation, will be productive of many incidental benefits, apart from their influence upon the floods and the commerce of the country.

In the progress of society, the power furnished by the rivers, limited to their low-water supply, often becomes inadequate to the wants of the population on their borders. This power may be vastly increased by the creation of small lakes to retain the surplus which is ordinarily wasted, until the natural flow becomes in-

sufficient, even where the navigation forms no part of the ultimate object.

In the far West, there are great rivers which send their periodic floods to the Gulf of Mexico, through planes of vast extent, which are waste and sterile for want of water. There is no navigation, because the streams are dry. The lands are unproductive, because, at certain seasons, there is no rain. Yet the floods of winter, if properly controlled, would suffice to irrigate the soil, extend navigation far into the interior, furnish power to manufacture the products which they would create, and thus spread wider the area of civilization.

The water need not be discharged directly at the site of the dam, and suffered to spend its power in producing the discharge; but it may be led off, by appropriate mains, to suitable ground for manufacturing establishments, and be there applied to useful machinery. In its descent, it may be arrested from point to point, brought many times into service, and finally sent on its last mission of good into the stream which it will make navigable, and capable of conveying the products which it has already aided to manufacture.

The water contained in the reservoirs upon the Alleghany could be advantageously used for the manufacture of all the lumber sent down that stream; and these reservoirs, ultimately extending navigation along that river into the State of New York, and connecting the navigable waters of the Mississippi with those of the Great Lakes and the Atlantic, by the Erie railroad and its branches, will be needed, in the progress of

time, to furnish the power for the manufacture of the products of a vast area along the Ohio, as well as around the northern borders.

Thus, a small portion of the cost of the artificial fountains of a single chateau would, in this country, enable us to control the floods of a river surpassing in grandeur the noblest stream of Europe—maintain constantly an uninterrupted navigation of 1,300 miles—create a water-power sufficient to convert into useful forms the products of all the country watered by the tributary streams, and give rise to cities which it would incidentally adorn with fountains such as the wealth of the "Great Monarch" of the last century could not purchase.

OF THE PROPER APPLICATION OF RESERVOIRS TO THE IMPROVEMENT OF RIVERS.

It is not intended to recommend the application of this mode of improvement to all streams. It is only those rivers, or parts of rivers, on which the imperfections of the channel are caused essentially by a deficiency of water in seasons of drought, and not by the rapidity of their fall, or obstructions in their beds, that are susceptible of this mode of improvement. Rivers which—like the Ohio, Alleghany, Cumberland, and Tennessee—are always navigable when there is sufficient water in their channels to float the boats freely, but of which the navigation fails because the supply of water fails, and on which lakes may be formed at small

expense, without injury to valuable property or to the salubrity of the country—such rivers as these can be best, most cheaply, permanently, and effectually improved, by collecting a portion of the waters which are wasted in producing floods, and holding them in store for the season when the sources of supply fail to render their customary tribute to the channel.

Such are the characteristics of the Ohio, and such are essentially those of all the great rivers of the Mississippi valley.

Many of these streams rise in the mountain ridges, and flow great distances through depressions parallel with the range in which they originate. Those which descend from the Alleghany break through the subordinate ranges of Laurel Hill, Greenbrier, Big Sewell, and other parallel and analogous formations, where many gorges are presented easy to dam up, and where the lakes to be formed will lie inclosed within a rim of rock, which will insure a purity equal to that of the waters of Erie or Ontario. Tens, and perhaps hundreds, of such sites are presented in the valleys of the Alleghany, Monongahela, Great Kanawha, and their tributaries; and, indeed, along all the rivers that flow from the mountains on either slope of the great dividing ridge.

It is not to be maintained that the water will become less salubrious because it is confined. The lakes which it is proposed to form are in all respects analogous to the great fresh-water lakes of the globe, which are provided with outlets to the ocean, through which the

water is slowly discharged, but, nevertheless, so adjusted as to retain the same water for a long series of years.

The salubrity of the fluid is not impaired by this exposure. The Falls of Niagara, probably, do not vent the volume of water which is contained in Lake Erie more than once in six or eight years; and it is certain that the contents of all the upper lakes would not pass over the cataract in half a century.

Nature relies, for effecting the change which is forever taking place in great bodies of fresh water, almost exclusively on the process of evaporation; and has provided that the fluid shall be thoroughly exposed to sun, and light, and air, by the agitation of its surface when in volume, and by its suspension in the clouds after its evaporation.

The healthfulness of the country cannot be impaired by the formation of artificial reservoirs in all respects analagous to those of Nature, liable to be drained off, to some extent, more than once in every year, and which need cover no vegetable matter in sufficient quantity to cause apprehension from the effect of its decomposition. These reservoirs are not intended to be wholly exhausted; and need only to be reduced at the surface, so as to lay bare a portion of their rocky borders.

But the salubrity of rivers, when no longer subject to become dry, and have their sands and vegetable deposits exposed to the summer's sun, must necessarily be increased; for the same experience which teaches that large masses of fresh water, existing as lakes, are salubrious, also teaches that shallow, stagnant pools, such as

are found in the place of an exhausted river, are deleterious to health.

It is difficult to imagine a serious objection to the improvement of this great natural system of inland navigation, by a method which accomplishes so much for an outlay so small—by a plan which places no incidental impediment in the way of trade, and the application of which is limited to no State or section of the Union.

From the base of the Rocky Mountains to the base of the Alleghany, there is not a great river or navigable tributary that may not be benefited by this process; while on the eastern slope of the dividing range there are numerous rivers flowing into the Atlantic, which have been improved by other means, and which must ultimately be subjected to this treatment, and relieved of the dams by which they are now obstructed.

The North Branch of the Susquehanna may be easily made navigable, from its mouth into the State of New York, for a convenient class of steamboats, by this simple expedient; and there are several rivers in Virginia, which, for an insignificant cost, may probably thus be supplied with abundant water for a permanent navigation.

The personal observation of the writer has not extended to the great rivers of the Southern States. But the elevations of their surfaces above tide, from point to point, seem to indicate that they are even more susceptible of the application of this method of improvement than those further north; while the Cumberland and

Tennessee, and the rivers of Kentucky, possess all the essential characteristics of the Ohio, and will always afford a good navigation for steamboats whenever they are adequately supplied with water.

Further west, the field of valuable improvement is immense. Probably two thousand miles of precarious navigation on the Missouri alone, may be rendered permanent and safe by a few dams constructed upon the great tributaries above the mouth of the Yellow Stone; and, as civilization is carried by steam into those distant regions, it is reasonable to suppose that the same incidental advantages to society will be experienced there, which, it has been shown, are certain to follow the application of this system on the Ohio.

It is not asserting more than the measurements presented in this paper will justify, when it is maintained that it is entirely in the power of man to control all the waters of the Mississippi and Missouri, and compel every river to flow with an even current, from its source in the Alleghany or Rocky Mountains, to its home in the ocean, forever free from the hurtful effects of floods and droughts.

The writer can scarcely hope immediately to remove the suspicion and distrust with which the first announcement of his plan was met by the public; but yet he believes that the period is past when prejudice or doubt can long resist the force of demonstration. When, in a former age, it was proposed in Spain to unite two rivers by a navigable canal, a commission of the Inquisition decided against the project on the broad ground

that, if it had been the will of God that those rivers should be united, they would have been joined in their creation. The decision was in conformity with the spirit of the age and the people, and was doubtless dictated by honest views of piety and right.

But times have changed, and men are learning to look upon this earth and all it contains as a gift from God to the beings of His creation, to be used, explored, studied, and improved.

The waters are not the least of these bounteous gifts. But it does not follow, because they are supplied in abundance, they were intended forever to be wasted. It is more in unison with what is known of the original design to conclude that the apparent excess was intended for many useful purposes—to be collected for the benefit of the parched earth; for the power that it affords; for the transportation of the products which it serves to increase and prepare; and not forever to burst, periodically, in a wave of destruction upon man and his works.

APPENDIX.

ON THE

BARS AT THE MOUTHS OF THE MISSISSIPPI.

EXTRACTED FROM A

REPORT TO THE WAR DEPARTMENT,

DATED JANUARY 8, 1851.

BY CHARLES ELLET, JR.,
CIVIL ENGINEER.

APPENDIX.

DESCRIPTION OF THE PASSES, AND NOTICE OF THE CHANGES WHICH HAVE OCCURRED IN THEIR CONDITION.

THE Mississippi River descends from New Orleans to the head of the Passes, a distance of about 95 miles, measured along the course of the stream, maintaining an average width of about 2,500 feet, a depth in the channel varying from 70 feet to probably 170 feet, and a velocity in high water of about 2½ miles an hour. The head of the passes is the point where the river divides its waters between two principal outlets; one leading to the gulf in an eastwardly, and the other taking a southwestwardly course. The former is known as the Northeast, the latter as the Southwest Pass.

Formerly, the Mississippi was correctly described as having three great outlets—there being then an intermediate root by which the water descended to the gulf in a direction corresponding very nearly with that of the main stem above its present point of bifurcation. But that Middle or South Pass has been slowly filling up for many years, and very rapidly within the last two or three years.

In 1722, this South Pass was examined by M. Pauger, an engineer in the employ of the Western Company, who was afterwards rewarded for his memoirs upon the country, and especially upon

the embouchures of the Mississippi, by letters patent, conferring on him a seat and a voice in the superior council of Louisiana.*

Pauger describes this pass as then "straighter than the ancient pass, but narrower;" and adds that "at the outlet of this pass there is a bar upon which there is but 9 to 10 feet of water, and which is about 100 toises wide."

If these soundings are correctly stated, they show an average draft on the bar of the South Pass, 129 years ago, of about 10 feet English.

By Gault's map, made from the admiralty survey, carried on from the year 1764 to 1771, we learn that the depth on the bar at the mouth of this pass, 45 years subsequently to the date of Pauger's report, was from 8 to 9 feet English.

The next, and doubtless the most authentic information concerning this bar which has yet been obtained, is that found in the report of George G. Meade, Esq., then principal assistant engineer, by whom it was surveyed under the direction of the special board of United States engineers, in 1838.

At the date of this survey, Mr. Meade says that "8 feet could be carried over the west and principal channel." But since that time material changes have taken place in all the passes, and especially at the head of the South Pass, where it is now scarcely possible for any useful craft to enter. A spit of sand has formed directly in the mouth of the pass, which has almost entirely closed up the entrance, and destroyed it for all commercial purposes. The probabilities now are, that unless some change be effected in the main stem of the river, such as might be produced by closing up existing outlets, or opening new ones, the progressive diminution of this pass will continue until it is converted into an inconsiderable bayou, or becomes filled up entirely.

The Northeast Pass, or a branch thereof called the Southeast

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* These facts are derived from the *Histoire de la Lousiane*, par Gayarré.

Pass, was, in the early periods of the navigation of the river, the principle avenue of its commerce. But it is probable that that preference was due rather to its position, favoring vessels to or from the east, than to the actual depth of water at its mouth. The earliest notices of the bars speaks of the entrance to the river as if there were *but one* that was used by the shipping. And it cannot be doubted that the Southeast Pass, or the Northeast Pass—which were in fact at that day, as they were fifty years later, but two distinct channels through the shoal-water at the outlet of the Northeast Pass—is the channel to which these early notices apply.

We find by a dispatch from Bienville, then governor, to the French minister, written in 1722, the following allusion to this outlet:—

"I have had the honor to inform the council, by my last letters, concerning the entrance of the river, and to assure them that vessels drawing not over thirteen feet (French) could then enter at full sail *without touching;* and that it would not be difficult to render the pass practicable for vessels of the largest size, the bottom being nothing but a soft and movable mud."

And he goes on to say, in the same dispatch, that he would already have undertaken the task of deepening the water on the bar, if the engineers who were especially charged with such works had concurred with him in opinion upon the practicability of the enterprise.

It appears, therefore, that the work which the hardy founder of New Orleans was prevented from attempting, for the benefit of a feeble colony, when the whole population did not exceed two hundred persons, has been postponed for a period of one hundred and twenty-nine years by the doubts of engineers, yet looked to for advice upon such subjects. From that day to this no attempt beyond a feeble commencement at dredging has been made to sweep out, or otherwise remove, that "soft and movable mud"

which still obstructs the entrance to the Mississippi, and embarrasses the richest commerce that has ever been bestowed upon this or any other nation.

We find from the preceding and other dispatches of Bienville, that in 1722 the Northeast Pass had a depth of full fourteen feet (English) on the bar.

In 1723, the engineer Pauger reports, that "on his first visit he found that vessels drawing fifteen or sixteen feet (English), or even more, passed easily." He calls the pass at the outer edge of the island of the Belize, the "veritable embouchure" of the river. He describes the bar, and gives his opinion of the cause of its formation, which is precisely that usually but most erroneously received at the present day, viz.: "*the weakening of the current of the Mississippi*, which discharges itself by numerous passes; and which, by encountering the sea in this place, forms here a deposit of soft mud five or six hundred toises wide." He expresses the opinion that this deposit "could be broken and carried off by stopping up some of the passes of the Mississippi by means of old vessels sunk to the bottom, together with trees, of which a prodigious quantity descends during the two first months of the year." He proposes dikes and brush-work for establishing the current of the river, suggests means of defence, &c.

In fact, we find in this report of the first engineer who ever visited the embouchures of the river, the original plan, which has been, as it were, stereotyped and reissued again and again in our own day. I will, however, defer the examination of this suggestion, until I have shown the true cause of the deposit which has place on the bar.

It seems certain, from the foregoing facts, that the actual depth of the water on the bar of the Northeast Pass, in 1723, was not less than 14 feet; that vessels drawing 14 feet could then enter at full sail "without touching;" and that others

drawing 16 feet, or even more, could be taken through—the bottom being a soft and movable mud.

By referring to Gault's map of the admiralty survey, from 1764 to 1771, we find that this pass then had 12 feet of water upon the bar.

By the survey made under the instructions of the special board of United States engineers, in 1838, the northeast channel still had a depth of 12 feet on the bar in low water; and this pass, which seemed to have maintained its depth of 12 feet for a period of seventy years, was then recommended by the chief of the Topographical Bureau as the one most suitable, from its position, to be improved by the process of dredging.

But great changes have taken place in all parts of the North-east Pass since the completion of the United States survey, and especially within the last two or three years. The soundings now show a general diminution of depth from the mouth of the Pass à la Loutre to the gulf. The bar has increased materially in breadth; the channel above it has contracted in width, and the draft of water upon it is so much reduced that it is not now deemed prudent to go out by this channel with a pilot-boat drawing 8 feet, unless it be in very favorable conditions of wind and tide.

The ancient pilot-station, known as the Belize, is no longer passed by the shipping, or any portion of the commerce of the Mississippi. It is still the home of the pilots, but they approach it from sea by entering at the Pass à la Loutre, ascending that pass to its source, and descending by the Northeast Pass, which still has good water down to the Belize Bayou.

There appears to me to be evidence that the bar at the mouth of the Northeast Pass has advanced about six miles since it was described by Pauger in 1723, and from three to four miles since the admiralty survey of seventy years ago. My impression is, that a repetition of the survey of 1838 will show a rate of pro-

great value at that time, but are now of comparatively little interest from the improved engineering skill of the present century.

To create a channel 30 feet deep through the northeast bar, which is the main requirement of the law directing the present investigation, it would be necessary to excavate to less than 12 feet at mid tide in mid channel. I regret it as a waste of time to speculate upon the practicability of such an undertaking. There are other channels now more favored by natural operations, which will relieve us of the necessity of encountering this task; and we must look to these for the means of accomplishing the intentions of the act.

In 1838, the Pass à la Loutre, a mere subdivision of the Southwest Pass, had a depth varying from 7 to 9 feet on the bar at its outlet. But since then, and especially during the last two years, within which space the main outlet of the Southwest Pass has been filling up, this arm has been as rapidly opening, and the Pass à la Loutre has now a minimum depth of 14 feet on its bar. This pass has accordingly taken the place of the ancient favorite entrance to the Mississippi for all inward and outward bound vessels of less than 13 feet draft, when the wind favors that route, and steam can be obtained to help them through.

It will be observed as somewhat remarkable, yet an important fact in devising a plan of improvement here, that although the actual depth of water can only be stated at 10 feet in this pass, yet vessels drawing 13 feet, and in one recent instance over 14 feet, have been brought in against the current. This difference between the depth of the water and the draft of the ship is of course due to the softness of the bottom—the material composing the bar of the Pass à la Loutre, and that of the Southwest Pass, being still, as it was described to be in the days of Bienville, "a soft and movable mud or slime."

This pass has also been pushed several miles to the east in the

last seventy years. Even its progress in the last twelve years is most distinctly visible. A shoal represented in the map of that day has been converted into a marsh—is now covered with vegetation, and raised entirely out of water. What was twelve years ago the edge of the gulf is now the "north channel," or a new and wide bayou, with an island nearly a mile in length stretching beyond it. New "mud-lumps" have risen up in the gulf where there was then 30 feet of water, and the whole form of the embouchure of the pass has changed.

In its present condition, this pass may be very easily kept open by a little labor, judiciously but frequently applied. I shall reserve a notice of the mode which I recommend for this object until I have shown the process by which these bars are formed and maintained.

The Southwest Pass is now used by all the ships of heavy draft that come up to New Orleans. It is, in fact, what the Southeast Pass was when visited by Pauger 129 years ago—the veritable embouchure of the river.

It is to the mouth of this pass that the 18 or 20 steam towboats employed in taking vessels over the bar, and up to New Orleans, come with their descending tows, or in search of vessels off at sea. But this bar has a depth of about 12 inches more water upon it now than was ever ascribed to the ancient pass by the Belize, and is safely crossed by vessels under tow drawing three feet more than could be brought in at either of the passes twenty years ago.

The actual depth of water on this bar may be stated at 15 feet; but no fact is better established than the passage of occasional vessels drawing 18 feet, and, in some rare instances, 19 feet, to and from the sea by this channel. Such passages are, however, only attempted in high water, and never without the aid of steam; though it is maintained that a ship will, *in time*, work its way through deeper mud under sail, and in the direction

of the current, than by the aid of two steam tow-boats of great power. But this is a very slow process; sometimes requiring several weeks for a ship to sail, or rather wallow through 4 or 5 feet of mud, where the rudder has no control of her course. Nevertheless, the fact is certain that vessels have been carried upon parts of this bar where the actual depth of water was 6, and even 7 feet less than the real immersion of the hull, and have gradually worked out unaided.

The channel through the southwest bar has shifted very much since the survey of 1838, and new mud-lumps have been thrown up at the edge of the gulf, where the width of the entrance for shipping is extremely small, and subject to frequent changes.

The depth of the pass above the bar does not seem to have varied sensibly since the date of the survey, where I tried the soundings, and I have no reason, based on actual measurement, to assert that the quantity of water flowing down the pass has materially changed; though there is ground to assume that there has been some diminution of the volume consequent on the opening of a new outlet above, of which I shall presently have occasion to speak. Yet the actual depth in the channel on the bar is greater now than it was twelve years ago, and this increase is attributed by observant men at the station, to the frequent passage of vessels, and the consequent stirring up of the soft mud, which is then swept out by the current. That this opinion is not unfounded will be hereafter shown; yet I am not prepared to draw from the fact the conclusion that a depth of 20 feet may be obtained by simply disturbing the bottom.

This plan, in common with every other plan of deepening the channels, excepting that of dredging, is based on the supposition that the bars at the mouths of the Mississippi are formed by the neutralization of the force of the river by the weight of the sea, where the waters meet at the edge of the gulf. This opinion, it will be found, is incorrect. The force of the river is not

neutralized, as supposed, and the deposit does not take place from that cause, nor originally at that point.

It is not necessary to the practical purposes in view, to investigate the causes which have conduced to the changes that have occurred, within the range of history or tradition, in the condition of the passes. There is one perpetual source of change in the constant prolongation of the delta. The land is every year pushed further into the gulf, and the bar is every year transferred, with equal step, to the outer points of the land. But, in addition, some of the recent alterations are referable directly to the creation of a new outlet, from the main stem of the river to the gulf, in West Bay, where a portion of the water attains the level of the sea at a point nearly thirty miles above the southwest bar.

This opening, known as "The Jump," was produced by cutting a ditch, or small canal, through the mud-banks which confined the river for a space of about forty miles on its approach to the gulf, for the purpose of taking oyster-boats by a shorter route into the Mississippi. This canal was originally provided with a rude lock to retain the water of the river and overcome the difference of level—amounting, at this point, probably to two feet. This frail structure was some years ago carried away during a gale. The river broke through and sought the lower level. The breach is now a quarter of a mile wide and sixty or seventy feet deep;* and the current passing through it is so rapid, at high water, that the tow-boats are obliged to give it a wide berth. Some, indeed, misled by the fog, have been drawn in, with vessels in tow, and lodged on the shoals below.

To this new outlet, which in the course of ages may become a

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* Mr. Thomas Lafarelle, civil engineer, informs me that he recently measured this bayou, and found it to be 1,250 feet wide, and in some places 60 feet deep.

Plaquemine or an Atchafalaya, is to be attributed many of the changes which have occurred at the head of the passes, at the mouth of the Pass à la Loutre, and in many other places. These changes are still progressing, and many years will pass before the equilibrium of the river, violently disturbed by changing the rate of descent, decreasing its slope below, and increasing it above the new outlet, interrupting the flow of all the water on one side of the river, and diverting that from the opposite side, will be re-established. The effects have not yet all been felt; but, though still progressing, they are not rapid enough, or sufficient to interfere sensibly with the operations which will be required to deepen the channel across the bars.

OF THE CAUSE OF THE FORMATION OF THE BARS.

In discussing the various modes which have been proposed for removing the bars, it has been uniformly assumed that the descending waters of the river are met at the mouths of the Mississippi, by the still water of the gulf, where the force of the river is neutralized by the resistance of the sea, and deprived of the power to transport its sediment;—that the sediment is consequently deposited on the bottom, and thus creates the bars which it is our object to remove.

Hence, to remove the deposit, it is proposed, in accordance with this assumption precedent, to restore the velocity which the river is supposed to have lost, and permit it thereby to regain its power to convey to the gulf the material which it has collected and brought forward from its ten thousand sources.

The whole of this plan is, however, based on a supposition which has no existence in fact. The velocity of the river is not destroyed nor very sensibly diminished at the bars.

When the river was rising, but still very far from being at full height, I measured the velocity of the current on the bar of

the Pass à la Loutre, and found it to vary at different times and places, from 3 feet to 3½ feet per second, or from 2 miles to $2\frac{4}{10}$ miles per hour.

I measured it also repeatedly on the southwest bar, and found there 3 feet per second, or about 2 miles per hour.

But there are many parts of the river where the speed of the current does not exceed two and a half miles, or even two miles per hour, in times of flood, and where it is, notwithstanding, more than 100 feet deep. In fact, on testing the velocity of the Southwest Pass four miles above the bar, and in five fathoms water, I found the current to be but two miles an hour—precisely the same as it was, under like circumstances of wind and tide, on the bar.

The force of the current, therefore, is not neutralized by the sea, and no such deposit can take place from the assumed cause, for no such cause exists. The plan proposes to remove a difficulty which has no existence—to restore a velocity which has never been lost.

The current of the Mississippi sweeps over the bars at the mouths of the passes, and, at periods of flood, many miles out into the gulf, with a velocity almost undiminished by its contact with the waters of the gulf.

But it has been suggested that the deposit at the bar is accelerated by the mixture of salt water with the fresh, which hastens the precipitation of the suspended material. This, doubtless, might occur, if the assumed mixture should actually take place to any considerable extent at the bar. But the supposition is not supported by the fact. The river water does not mix suddenly with the sea, but rises upon it, floats over it, and rushes far out into the gulf on the top of the denser sea-water, by which it is buoyed up.

I tested this point repeatedly, and found uniformly a column

of fresh-water nearly 7 feet deep in the gulf, entirely outside of land, and salt-water at a depth of 8 feet below the surface, and extending thence to the bottom. The passage from fresh-water to salt-water was extremely sudden both at sea and on the bar.

In fact, the river does not come down with a certain normal depth and speed and encounter the gulf at the bar, and there lose its power in the contest. No such process takes place. The fresh-water is lighter than the sea-water, and floats upon it, as oil or any other lighter material floats on the surface of fresh-water, or as the atmosphere rests on the surface of the sea. There is no sudden union or consequent precipitation. There is no sudden destruction of velocity or consequent deposit of suspended silt. The river-water, in virtue of its lesser density, rises upon the sea-water, glides smoothly over it, passes out to the gulf, and slowly mixes with the sea-water, as the column spreads over a wider area, diminishing in depth, and is agitated and broken by the wind.

But the water of the Mississippi does not move over the surface of the gulf at a speed of 3 feet per second without imparting a portion of its motion to the sea. The equally impressible and fluid salt-water, rubbed by the river which floats upon it, is carried forward by the friction developed at the surfaces in contact. The fresh-water and the salt-water take the same direction, towards the sea, and with nearly the same velocity, but yet keep separate.

This state of things clearly cannot exist to the bottom; for, as the river-water is forever coming forward, if the salt-water all flowed towards the gulf it would all be carried out, and river-water would take its place. Fresh-water would then be found at the bottom, according to the supposition on which the plan of deepening by contracting the channel, or stopping up the bayous, depends. Salt-water must come in from some quarter to supply the current of sea-water that is forever setting towards the gulf,

beneath the water discharged by the river. This salt-water can only come from the sea, and can only come in *along the bottom.*

It is, in fact, the principle of the *eddy* that is here at work, the movements being exhibited in a vertical instead of a horizontal plane.

Now, the question is, how does this account for the existence of the bar? The fresh-water running out cannot produce the deposit, for it has velocity enough to sweep away a foundation of coarse gravel. The outpouring salt-water, immediately beneath the fresh, cannot produce a deposit, because it also has a velocity, seaward, strong enough to remove anything that is brought down by the Mississippi. The salt-water *coming in from the gulf* might produce, and I doubt not does produce, a deposit; for it passes over the soft muddy bottom of the gulf, and moves into the river and along the bar at a very slow rate.

According to these facts and this reasoning, there must be usually on the bars three distinct strata of water:—

1. Fresh-water running out at top, found, by experiment on the southwest bar, to have a velocity of 3 feet per second.

2. Salt-water below the fresh, also running out, with nearly the same velocity at top; and

3. Salt-water coming in slowly along the bottom, and *apparently* a sheet of salt-water between that running out and that coming in, which will be without motion.

But, as already said, and as is obvious, all the sea-water that comes in must go out again. It comes in along the bottom, and it must go out between the column of salt-water coming in and that of the fresh-water going out. Each particle of salt-water, therefore, must change its direction and position in elevation. It must pass from an inward-bound lower strata, to an outward-bound upper strata. But in passing through this change of motion its velocity up stream must be neutralized. It passes, to use a technical term, the "dead point." At this point it may

cease to bear its whole burden of mud, *which it has brought from the gulf*, further forward. It leaves it, or a portion of it, at the turning-point. This turning-point is the place where the bar, for the time being, is in process of formation. But as the upper and lower strata are moving in opposite directions, the intermediate column must, of necessity, have a rotary motion; that motion must be shared by the lower column of salt-water, and this turning-point must, therefore, be found at the same time at different places along the bar.

But the river is constantly fluctuating in height, and discharging different volumes of water into the gulf. The height of the gulf varies with the state of the tides and the winds. The head or upper reach of salt-water is therefore variable. When the level of the gulf is high, and that of the river low, the sea extends many miles up into the river. But the motion is then small, for the volume of water discharged by the river is then comparatively inconsiderable, and is not competent to give sensible motion to the great depth of sea-water which, under these conditions, is found above the head of the passes. The deposit, consequently, though still taking place, is insensible in the deep channel of the river. But when the river is high, it pours into the gulf a vast volume, and carries the sea-water, by rubbing over its surface, gradually back nearly to the mouth of the river. This is the usual state of things, and it is therefore near the mouth of the river that the deposit is usually made.

That portion of the deposit which is formed in the bed of the river during its low water, when the sea sets far up, is swept out again when the river rises; while that portion which is formed near the mouth of the river when the Mississippi is in flood, is only removed to a small, and scarcely perceptible extent, when the river is low and the salt-water is circulated by the tide over the bar.

I have thus endeavored to explain the mode in which these

bars are formed, upon established mechanical principles. It remained to verify and confirm the correctness of the conclusions by direct observation. For this purpose, when the river was at about half its greatest elevation above low water at New Orleans, I went out into the gulf, beyond the extreme mud-lumps at the mouth of the Southwest Pass, and filled a bottle with water at the bottom, where the soundings showed 26½ feet. The contents drawn up were sea-water. At every other depth up to eight feet from the surface, the contents of the bottle were salt-water. At seven feet, and all depths less than seven feet, the water was perfectly fresh and muddy. The line between fresh-water and salt-water, in the gulf, was distinctly marked, and was found between the depths of six and eight feet from the surface.

The column of fresh-water was nearly or quite seven feet deep, and sweeping out on top of the salt-water over a width of 7,000 feet, with a speed of three feet per second. The wind during this experiment was down stream, and almost in the axis of the river.

On a subsequent day, when the wind had shifted, and was blowing with much force directly up stream, I repeated the same observations, at different points along the bar, and found the same results. In each case the fresh-water, running rapidly out, extended to a depth of nearly or quite seven feet, and the salt-water immediately beneath it was making rapidly in the same direction—to the gulf. This could be easily observed in sounding; for the lead, after passing through the fresh-water, was still carried forward by the sea-water beneath. But it required a more careful experiment to make the *inward current* along the bottom perceptible; for the pressure of the two upper strata, respectively, of fresh and salt water upon the line, overcame that of the refluent column at the bottom, which is comparatively feeble, upon the lead.

To ascertain properly the direction and force of the current

at the bottom, I procured a hollow iron vessel, filled it with water so that it would sink, and suspended it by a fine wire. The current of fresh-water, seven feet deep, carried this vessel rapidly towards the gulf; and, when sunk to the depth of the salt-water under the fresh, it was still carried forward in the same direction, and apparently with nearly the same force; but, when it reached a point within three or four feet of the bottom, *it began to return, and was brought by the inward current along the bottom rapidly up stream.*

The under-tow thus became distinctly visible, and was found to extend at that time nearly to the head, or inner edge, of the bar.

These experiments were made in a pretty high stage of the river; but there must, of necessity, be an under-tow, or an up-stream current of water along the bottom, in every possible condition of the stream. It only changes in strength and position with the ordinary changes of the controlling facts—winds, tides, and volume.

There is an under-tow which is sometimes detected by the pilots, by the want of steerage of their vessels at the bar. But this is an under-current proceeding from peculiar causes. It occurs when the sea-water is set, by the high winds and flood-tide, into the mouth of the river, while there is yet a sufficient volume of fresh-water flowing out to make a perceptible upper-current. But a refluent current of salt-water must exist, from the principles here exposed, in every condition of wind or tide, so long as the Mississippi sends its waters to the gulf, be the volume great or small.

It will be readily seen, from the facts and reasoning here submitted, that the material composing the bars at the embouchures of the passes is always in a state of most unstable equilibrium; that it is undergoing perpetual change, floated off by one eddy and left by another, and needing only a slight disturbance of the actual forces to remove it entirely.

OF THE MUD-LUMPS.

In the foregoing description of the process by which the bars are produced, I have taken no account of the "mud-lumps" which are found at the outlets of all the passes, and generally, but by no means universally, at the outer edge of the bars. I do not doubt that these remarkable formations are produced by the uplifting of the bottom, though I am not able to give any satisfactory explanation of the origin of the upheaving force.

These lumps have considerable firmness of texture, and are liable to rise, and sometimes do rise, directly in the channel, creating shoal-water where there was previously sufficient depth, and entirely changing the entrance for ships. No process of improvement is likely to prevent this occurrence; and, when the lumps appear, if in the way, the channel must be shifted, or they must be cut out—a work of no peculiar difficulty, since they are usually, when near the channel, of inconsiderable dimensions, and surrounded by deep water.

PLAN OF IMPROVEMENT BY DIKES OF BRUSH-WORK.

The mode in which the bars are formed and maintained having been determined, we are in a condition to submit each plan of improvement that may be suggested to a certain test of its efficiency, viz.: its accordance with the laws which govern the creation of the deposit.

If we increase the velocity of the fresh-water current by contracting the channel, or by stopping up the secondary outlets, we shall certainly increase the depth and velocity of the column of fresh-water flowing into the gulf on top of the sea-water. But *that* will not sweep out the bar. No part of the fresh-

water comes within eight feet of the top of the bar which it is expected to remove.

The immediate effect of this increased force of fresh-water will be to carry the upper portion of the salt-water immediately below it, further out, and to transfer the place of deposit to some other point, still on the bar, but nearer the sea; just as it is now transferred sometimes from above the head of the passes, where it is occasionally found in extreme low water, to within half a mile of the edge of the gulf, to which point it recedes in common high water. But this will not prevent an under-current of salt-water from flowing in, and an upper-current from flowing out; nor will it prevent the deposit from taking place at the points where the direction changes, though, with the same volume of water, it will change the position of that deposit.

That this conclusion is correct, is sustained not only by the reasons which have been adduced, but directly and practically by the fact that there is a stronger current now at the mouth of the Pass à la Loutre than at that of the Southwest Pass; yet the channel is deeper on the southwest bar than on that which is found at the entrance of the Pass à la Loutre. It is sustained, also, by another fact, which is asserted by those who reside at the Belize, and who are best acquainted with the periodic changes to which the depth of the channel is subject. It is the circumstance that the water is rather deeper on the bar when the river is low and the sea sets in, and there is a very feeble outer-current, than it is when the river is high and the velocity seaward is greatest.*

While the effect of increasing the velocity of the current by

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* I find this fact set forth in the report of William H. Slidell, Esq., civil engineer. It is susceptible of satisfactory explanation, and is confirmed by the assurances of all the pilots with whom I have conversed on the subject.

contracting the embouchure of the river will not be felt in the removal of the bars, this increase of current will take place at the surface, and hence act with increased power upon the very works by which it is produced. These works must rest on a foundation of loose mud, which has been deposited in the existing order of things. There is, therefore, reason to believe, at least to apprehend, that any material increase of littoral velocity would carry off this deposit, undermine the works, and consequently overthrow them.

The same objection, and others not less grave, apply to the other ancient plan of stopping up some of the outlets, and turning all the water into one or more of the passes which it is proposed to keep open. This expedient is based on the same errors as the preceding—the supposition that the bar is produced by the neutralization of the force and velocity of the river, attributable to the resistance of the sea, and the hope of restoring both by augmenting the volume of water discharged by the pass to be improved. It has been sufficiently shown that the increase of the force of the current will only change the position of the bar, but cannot prevent its formation; and that the increased speed of the current will be only at the surface, while the refluent undercurrent, which brings in the light mud from the gulf, must continue to leave a deposit where its direction is changed. But to throw a greatly increased volume of water into any one of the passes, must of necessity scour out that pass, before it approaches the sea, to a greater depth, cut away its borders, and raise its surface higher. The material of which the banks of the stream is composed will not bear this usage. Indeed, the river is now, at high water, so nearly level with the marsh that retains it, that the borders are overflowed, at times, alternately by both the river and the sea. A large increase in the volume of water discharged by any one of the passes must result in the creation of new openings through this soft material, and thus give vent to the excess.

Along the forty miles of the Mississippi next to the gulf, there are numerous points where the salt and the fresh water approach within a few hundred feet, and where the labor of three or four men could create new bayous, or new "jumps," in a single day. Any one of the passes may be promptly closed up, and the river may be concentrated at low water in either of the channels; but no labor that can be obtained for such a purpose will suffice to maintain the integrity of that channel permanently in high water. I regard this plan, therefore, as impracticable in the execution, and as certain to result in disappointment if it could be accomplished.

DREDGING.

The plan of deepening the bars which has, perhaps, been sustained by the highest authority, is that of dredging. The experiment was tried, I think, in the years 1838–39, under the direction of the Topographical Bureau. But the result was not propitious. The Northeast Pass, where the effort was made, is now filled up, and abandoned; while the Southwest Pass, where the mud is frequently stirred up and the water agitated to the bottom, by the passage of vessels in tow, is now deeper than any of the passes have ever before been maintained across the bars.

Still, I do not doubt that a sufficient number of dredging-machines could be applied to open and preserve any one of the channels. The process by which the deposit takes place indicates that the accumulation is very slow. The uniform height of the bars for more than a century, during which period they have advanced some miles into the gulf, shows that the water is forever making and forever removing the deposit. The contending forces are now equal, and there is nothing to resist the new force that may be applied by art. It would be perfectly practicable, therefore, to remove the bar and keep the channel open.

But a dredging-machine works at great disadvantage in this soil. The position is extremely exposed, and it is only in favorable weather that it can work at all; and, when the work is interrupted, the whole force—of machines, steamboats, hands, and tenders—is idle, and must be maintained. The outfit is very costly, and the greater part of it valueless when the work is done. Besides, such a machine works only in spots, and its labor is of no value until the whole passage is cut through.

In a report made to the Topographical Bureau in 1837, the cost of dredging a channel 300 feet wide and only 15 feet deep, through the northeast bar, was estimated at $160,000;* and, in a report of the chief of the Topographical Bureau, in 1839, the cost of dredging an 18 feet channel, through the same bar, is estimated at $557,000.

I have no doubt that the cost would have come fully up to these estimates if that plan had been carried out; but I feel equally well assured that such a channel as was contemplated by the latter can be obtained in the Southwest Pass for a very small fraction of the cost of opening it by dredges.

A depth of 15 *feet, which is all that was contemplated in* 1837, *is now maintained by the mere passage of vessels;* and, in my opinion, a depth of 18 feet may be opened in a few months, across the same bar, by a single steamboat.

SHIP CANAL.

The obstructions at the mouth of the Mississippi have long been regarded as of great and almost insuperable difficulty. The various plans which have been offered for removing these impediments have generally been suggested as mere experiments

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* Report of Captain W. H. Chase, February 10, 1837.

that ought to be tried, and which might possibly result in success.

On this belief, that the maintenance of a channel through the bar was an undertaking of immense labor and doubtful result, it was proposed, some years since, to evade the difficulty by constructing a *ship canal* from the river out into the deep water of the gulf. A report in detail, favoring this plan, was made to the Topographical Bureau in 1837. The prompt commencement of the work was forcibly recommended in the report, and the estimated cost was set down at $10,000,000.

I do not mean to express any doubt of the physical possibility of constructing a ship canal even on the treacherous soil at the mouth of the Mississippi; but I conceive that an open channel through the bar will be incomparably better than a work embarrassed by locks and such other impediments as attach to the use of any canal by heavy vessels. I am confident, moreover, that an open channel of any desirable depth can be formed and maintained forever for about one year's interest on the estimated cost of the canal, and which will be free from all its inconveniences.

PLAN OF DEEPENING BY STIRRING UP THE MUD.

Persons who are familiar with the character of the material composing the bars are very generally of the opinion, that if the bottom were stirred up frequently, by dragging scrapers over it, as the tide ebbs, and when the river is high, the light mud would be carried off to sea by the river. This is now, in fact, the prevailing opinion among the intelligent pilots at the Belize and Southwest Pass; and they sustain their views by referring to the actual deepening of the channel on the southwest bar, where all the heavy shipping is accustomed to enter.

I do not doubt that this pass is kept somewhat deeper—per-

haps a foot deeper—than it would otherwise be, by this cause. But the simple remedy proposed, although it cannot fail to improve the channel, will not produce all the effects that are desired.

It has already been shown that the lower four or five feet of water on the bar is sea-water running up stream, while the next four or five feet is salt-water running down stream; and that, from the nature of the forces at work to produce these motions, a rotary movement must necessarily have place in a vertical plane, by which the salt-water of the bottom is constantly brought towards the top, and a portion of the upper strata of salt-water is transferred to the bottom. It follows, therefore, that unless the light mud be so stirred up as to be brought into the current of fresh-water flowing out, or at least into the upper portions of salt-water passing out, it cannot be carried off except in very small quantities. Unless this be done, a large proportion of the material will be redeposited. To reach the proper level, the water must be so agitated that the disturbed mass will rise *at least* seven feet above the bottom.

The movement of ships through the mud, while cutting a furrow, as they often do, from one foot to three feet in depth across the bar, can raise but a very small part of the matter which they put in motion to a level seven feet above the bottom, or ten feet above their keels; and, consequently, must release an extremely small portion of the mass from its place in the bar. Still, that very small portion, stirred up and carried off by the passage of four or five vessels a day, has had a sensible influence upon the depth of the southwest channel."*

* The whole number of vessels taking pilots in 1850, at all the bars, was about 2,720. Of these, in the winter and spring months, on an average, about eight each day passed the southwest bar; and about one-half of these, or four a day, probably, have draft sufficient to disturb the bottom more or less.

A steamboat of proper construction might, in good weather, running constantly forth and back, cross the bar and scrape up the bottom from 20 to 30 times in every 12 hours. Allowing for night-work on the one hand, and inclement weather on the other, I think 25 trips might be counted on daily.

That this process would ultimately produce a depth of 17 feet, or perhaps 18 feet, I do not doubt, but it would become less and less efficient with every increase of depth.

To do the work effectually the bottom must not only be disturbed, but it must be *lifted*, and brought within the reach of the upper current setting into the gulf. This may be effected, to some extent, by the form of the scraper. But a very simple expedient may be adopted that will do the work thoroughly, and bring the material rapidly to the surface in the best possible condition to be carried off to sea by the river.

Instead of scrapers, or drags, I would recommend the use of tubes, or hollow wrought-iron cylinders, to disturb the bottom. These should be attached to the bow, stern, and sides of a steamboat of construction fit to encounter the exposure of the situation. A steamer, similar to the smaller class of boats used in towing vessels from the gulf to New Orleans, would be competent for the duty.

The cylinders should be of wrought-iron, 18 or 20 inches square, and about 20 or 25 feet long, and open at both ends. They would need, of course, to be firmly stayed, and admit of adjustment to suit the varying depth in the channel.

The lower and forward end should be sunk deep enough to cut eight or ten inches into the soft mud of the bar, and the upper end should lead nearly or quite to the surface of the water. Each tube should have an inclination from the surface towards the bow of the boat; the forward end being down and cutting into the mud of the half-fluid bar.

I need not say that while the boat is at rest no water will pass

through the tubes; but that when it moves, the mud and water will rush in at the bottom and out at the top of every tube, and be thrown up to a height due to the speed of the boat—say 12 or 15 inches above the surface.

The water will rush in at the bottom at the rate of 9 or 10 feet per second, carrying the light mud of the bar with it, completely mixing up and saturating every particle of the material, and discharging it on the surface of the water in a fluid state, whence it will be swept into the gulf in 15 or 20 minutes.

A good boat would probably be able to make six or seven miles an hour, armed with six or eight such tubes on each side; and such a boat would, consequently, send out 14 or 15 streams of mud, or mud and water, flowing as fast as her own average motion through the water.

I cannot well imagine a condition of things which would enable us to remove a bar as promptly, or as cheaply, as it can be done at the mouths of the Mississippi. The bottom is remarkably clear of logs or other substantial impediments. The softness of the material will permit it to flow through the pipes to the surface, and the rapidity of the upper current will insure its immediate conveyance to the gulf. Fourteen or fifteen copious and continuous streams of diluted mud will pour through the pipes as rapidly as the boat can move, and be transported as fast as the river flows.

That the channel will be filled up to some extent by the material of the bar adjacent to the deepened passage is not only probable, but certain.

This stuff cannot stand without support, and will flow in as an imperfect fluid until its surface approximates a level. But the efficient plan here suggested will remove it all as fast as it comes in, and speedily produce a channel of the most ample width. It cannot require over three or four months of high water, with a

proper outfit, to open a passage as wide and as deep as can be needed for commercial purposes.

But the power which originally created the bar, and still serves to transfer it from point to point, *pari passu* with the advance of the delta, cannot be prevented by art from contributing to act. The causes which originally produced the deposit will reproduce it, and the channel can only be kept open by continued labor. But this labor will not be serious. The mode in which the deposit takes place is evidence that the process is slow, and that it can be easily kept down when once properly reduced.

More than a thousand steamers now float on the Mississippi and its tributary waters, engaged in the transportation of its commerce. If one of this thousand boats should be detached for the purpose of removing the greatest obstruction to that commerce, it could not be felt as a serious tax on the common interest.

NOTES.

NOTES.

NOTE A.

It is not deemed necessary to burden this paper with the details of the observations on the relative velocities of the currents at and beneath the surface. The results are correctly stated in the text, and show conclusively that no error of any practical value can be committed by computing the discharge of the Mississippi from the surface-velocities; though great errors might be made by relying on the speed of the central currents.

The details of the observations upon which the writer's conclusions are founded, will be given in a supplemental paper.

NOTE B.

The statement here given of the discharge of the Mississippi at Memphis, as deduced from the observations of Mr. Marr, needs special explanation. The average daily discharge, as it is given in Mr. Marr's report, for nine days of extreme high water, was

74,530,955,174 cubic feet:

or, at the rate of

862,626 cubic feet per second.

But, in the calculations from which this result is obtained, an allowance of a fraction over ten per cent. was made for an assumed retardation of the water beneath the surface.

The experiments of the writer not having authorized such an allowance, the ten per cent. so deducted has been restored, in order to obtain the result of the measurements at Memphis, when calculated in the mode adopted in this paper—that is, from the surface-velocities.

Some of the observations of Mr. Marr show a discharge at Memphis, in 1850, of 1,040,000 cubic feet per second, when no deduction is made on account of the supposed average retardation of the mass of water beneath the surface.

NOTE C.

It was the intention of the writer to discuss this formula, in some detail, in a note to the text. But being under the necessity of submitting his Report to the War Department hastily, and wishing to test the formula further on shallow mountain streams, he is compelled to reserve this discussion, which will also form part of a supplemental paper.

NOTE D.

The level of low water in the Ohio River, at Cincinnati, is 432 feet above tide. The surface of Lake Erie is 565 feet above tide.

By the recent survey of the Ohio and Mississippi Railroad, by Mr. E. Gest, Civil Engineer, the level of low water in the Mississippi, at St. Louis, is ascertained to be 146½ feet below Lake Erie. Hence, low water in the Mississippi, at St. Louis, is 418½ feet above tide.

The level of low water in the Mississippi, at the mouth of the Ohio, as ascertained by Mr. John Childs, Engineer of the Mobile and Ohio Railroad, is 275 feet above tide; whence the fall of the Mississippi, from St. Louis to the mouth of the Ohio, is 143½ feet; or, assuming the distance to be 200 miles, at the rate of 8½ inches per mile.

There is certainly no conclusive reason for questioning the correctness of this result. But the descent of the Mississippi above the mouth of the Ohio, which it exhibits, is so much greater than appears probable,

that the writer is almost compelled to suspect some error in the determination of the height of low water at St. Louis.

If the average descent of the Mississippi, immediately above the mouth of the Ohio, be 8½ inches per mile, the elevation of its low-water surface, at Commerce, will be 295 feet above tide.

NOTE E.

The following passage in the Report already noticed, of passed-midshipman Robert A. Marr, deserves attention :—

"It has been estimated that of the rain-water falling in the valley of the Mississippi, only $\frac{1}{1000}$ part reaches the gulf. What proportion is lost after once getting into the channel, is, I believe, not known. Between Memphis and Vidalia, there are immense tracts of overflowed land; and, according to the above hypothesis, immense quantities of water may be taken up by evaporation, and wafted by the winds, to swell the currents of far-distant rivers; may disappear through the fissures in the bed of the Mississippi itself, or be absorbed and filter through the overflowed earth to fill the capacious chambers of subterranean reservoirs."

No authority is given in the Report for this extraordinary estimate which, it is proper to say, is altogether erroneous. The discharge through the channel below Red River, *in a single day*, is about ten times as great as the above estimate for the whole year. The fraction $\frac{1}{1000}$ should have been about $\frac{1}{3}$; its *precise* value not having yet been ascertained.

NOTE F.

The following speculations concerning the future progress of the population of this continent, are found in the *Encyclopædia Britannica*, article "America :"—

"We know with certainty that a prosperous community, possessing

abundance of unoccupied land, will double its numbers in 25 years, *without any aid from emigration;* and, as the scale ascends in geometrical ratio, a short time necessarily produces a wonderful change. It is to be observed, however, that the whites, possessing the advantage of superior industry, order, and forethought, naturally increase faster than the other classes. In the United States, this part of the population increases at the rate of three per centum per annum."

In this article, the white population of the American continent is assumed to have been 21,000,000 in 1830, and to increase at the rate of three per cent. per annum; from which data the following results are obtained:—

Number of whites in	1830	. . . .	21,000,000
" "	1855	. . . .	42,000,000
" "	1880	. . . .	84,000,000
" "	1905	. . . .	168,000,000
" "	1930	. . . .	336,000,000

These speculations are carried still further in the article quoted. But they do not include the great element of all such computations when applied to the United States, viz.: the accessions to the population of this country from foreign emigration.

The above results, however, are sufficient to lead the reflecting mind to a safe conclusion on the question—Whether the delta of the Mississippi is or is not to be wholly reclaimed and brought under cultivation?

NOTE G.

The late John McDonough, in reply to certain questions proposed in a circular issued by a joint committee of the legislature of Louisiana, in 1850, says: "When he first travelled the banks of the Mississippi, fifty years since, on horseback, he was forced to swim his horse across at least twenty or thirty different bayous—some of them fifty to sixty

feet in width—which crossed the path he travelled and entered the river."

These bayous were encountered in his journey along the west bank of the Mississippi, between the Bayou Plaquemine and Red River. But there were other similar outlets leading also from the river into the swamps and lakes on the east bank; all of which, on both sides, have been stopped up in the progress of improvement.

NOTE H.

The term Old River, is the local name of the old channel of the Mississippi at the mouth of Red River. At this point, and immediately below, the Mississippi formerly exhibited two great bends, the lower and greater of which was cut off by the State of Louisiana in 1848, and has been frequently referred to in this volume as the Raccourci cut-off. The upper of these bends was cut off at an earlier period, by the late Captain Shreeve, for the purpose of shortening the navigable channel. The portion thus cut off is now known as Old River.

Red River, as stated in the text, discharges into this old channel; and the Bayou Atchafalaya, which has an independent outlet to the Gulf of Mexico, has its source in this Old River, two or three miles below the mouth of Red River.

NOTE I.

The following is the table computed by Professor Riddell, for the height to which given volumes of water, admitted into the upper end of Lake Pontchartrain, would raise the surface of the eastern part of the lake. [Report of Joint Committee on Levées.]

Cubic feet of water discharged per second.	Corresponding elevation of the lake in feet and decimals.
46,756	0.027
93,513	0.111
140,269	0.250
187,026	0.444
233,782	0.694
280,539	1.000
327,295	1.361
374,052	1.777
420,808	2.250
467,564	2.777
514,320	3.361
561,078	4.000
607,834	4.694

This table may be used as a numerical approximation to the law by which the height of the lake, above a stationary or tideless sea, must increase, in order to force given volumes of water through the passes; but not as any approximation to the practical effect which a given volume, admitted into the lake, would have in elevating its surface.

NOTE K.

The average volume of water annually flowing down the Ohio is shown in the text to be 835,000,000,000 cubic feet. This volume would fill a lake 100 feet deep and 17¼ miles square.

To have regulated the supply of the river in 1848, so as to have kept the depth on the bar at Wheeling uniform throughout the year, would have required reservoirs capable of holding 240,000,000,000 cubic feet, which is equivalent to a single lake 100 feet deep and 9⅛ miles square.

There is no difficulty, on any of the principal tributaries of the upper Ohio, in obtaining reservoirs capable of holding from twelve to twenty thousand millions of cubic feet. It can scarcely be doubted that twelve

or fifteen sites for dams may be selected capacious enough to hold all the excess of water, and equalize the annual discharge so nearly, that the depth may be kept within a very few feet of an invariable height.

NOTE L.

It is by no means improbable that by the aid of some improvements of the channel, a sufficient depth of water may be constantly maintained in the Ohio, at Louisville, to permit boats to *ascend the Falls* at all times, and thus supersede the necessity of a new and enlarged canal. But the measurements now in the possession of the writer having been all made at Wheeling, and applied to the records kept at that point, he cannot express a positive opinion upon this important question. The results, as far as they go, point to an equalization of the daily discharge of the Ohio, as, possibly, the cheapest mode of improving the Falls; making even that work an incidental consequence of a systematic and adequate improvement of the general navigation of this river and its tributaries.

NOTE M.

Although there has never been any attempt made, or proposition offered, to supply the channels of great navigable rivers from stores of water held in reserve, as is here contemplated, yet experiments have been made, and expedients resorted to, in various practical operations, so analogous to this method, that they ought to have led to some such suggestion.

It has long been the practice on some of the smaller rivers of Europe, to erect movable dams, to retain the water of the streams, and overflow the shoals above the dams. After which, when the boats have passed the upper shoals, the dam is lowered, and the boats allowed to descend with the water of the pool; and, keeping on the top of the wave, they are thus enabled to pass over the shoals below.

A similar expedient has been long in use on Oil Creek, and some of the other tributaries of the Alleghany River. The lumber men there frequently send their lumber from the smaller tributaries into the larger, by opening the sluices of their mill-dams, and creating a flood sufficient to float their rafts into deeper water.

The Lehigh Navigation Company of Pennsylvania were compelled, for many years before the completion of their improvement, to send their arks, loaded with coal, down the channel of the Lehigh by the same process. The fall of the river was rapid, and the supply of water very insufficient. The arks were floated through the pools formed by the dams, and passed by locks into the channels below. The water was then drawn through sluices from the pool above the dam, and the coal-boats were borne on the top of the wave over the shoals in the channel.

The Schuylkill Navigation Company have been in the practice for years, when their boats have grounded in the pools from want of water, of increasing the depth by drawing water through sluice-gates in the dams above. Even the small dams on that river are so supplied with gates for venting the water, that the stream is kept in complete control during the summer season. By opening the gates the pond above is emptied, and a small flood is produced below. By closing the gates, the supply furnished by the river is held back for many hours, while the empty pool is being replenished. During that time no water reaches the channel below.

NOTE N.

Record of the daily height of water on the Wheeling Bar for the years 1838 and 1841.

RECORD FOR THE YEAR 1838.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	—	—	—	11	17	16	6½	2⅛	1⅜	1	1½	3
2	—	—	—	9	15	14	7	2⅛	1⅜	1	1½	3
3	—	—	—	8	15	12	6½	2⅛	1⅛	1	1½	3
4	—	—	—	7½	17	10	6	2⅛	1⅛	1	1½	3
5	—	—	—	7	19	9	6	2¼	1⅛	1	2¼	3
6	—	—	—	6½	24	9	5½	2¼	1¼	1	4	2⅜
7	—	—	—	6½	31	9	5½	2⅛	1⅛	1	6	3
8	—	—	—	6	29	9	5	2	1¼	1	8	3
9	—	—	—	7	26	12	4½	2	1⅛	1	9	3
10	—	—	18	8	20	10	4	1⅞	1⅛	1	9	
11	—	—	13	11	16	8	5⅜	2⅛	1¼	1	9	
12	—	—	13	13	14	8	3½	2⅛	1⅛	1	8	
13	—	—	15	10	12	7	3½	2⅛	1⅛	1	7	
14	—	—	17	11	10	7	3½	3	1⅛	1	6	
15	—	—	20	10	9	6	3¼	3	1⅛	1	5	
16	—	—	22	9	8	7	3	3⅛	1⅛	1⅞	5	
17	—	—	22	9	8	7	3	3⅛	1⅛	1	5	
18	—	—	20	14	15	8	3	3⅛	1⅛	1½	7	
19	—	—	16	14	18	8	2⅞	2¾	1	2¼	9	
20	—	—	16	15	17	8	2⅞	2¾	1	2¼	11	
21	—	—	17	14	15	8	2½	3⅛	1	2¼	9	
22	—	—	22	13	13	7	2⅛	3¼	1	2⅛	8	
23	—	—	25	12	13	7	2⅛	2⅞	1	2⅛	7	
24	—	—	24	10	18	8	2⅛	2⅞	1	2⅛	6	
25	—	—	26	15	22	9	2⅛	2⅛	1	2	5	
26	—	—	25	16	20	10	2⅛	2¼	1	1⅞	4½	
27	—	—	24	16	18	9	2⅛	2⅛	0⅞	1⅜	4	
28	—	—	20	15	15	8	2⅛	2	0⅞	1⅜	4	
29	—	—	16	15	15	7	2¼	1⅞	0⅞	1⅜	3½	
30	—	—	14	16	16	6½	2¼	1⅜	0⅞	1½	3	
31	—	—	13	—	16	—	2⅛	1⅜	—	1½	—	

NOTE N—*Continued.*

RECORD FOR THE YEAR 1841.

Date.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	—	14	4½	28	15	5	5	2	1¼	3	3	7
2	—	12	5	24	18	4⅝	4½	2	1⅛	3	3	6
3	—	13	6	20	18	4½	4½	3	1⅛	2⅝	3	5½
4	—	13	7	18	16	4¼	4	2⅝	1⅛	2⅝	3	5½
5	—	11	7	17	14	4	3	2⅝	1⅛	2⅛	3	6
6	—	9	7	15	12	4	5½	2⅝	1	2⅛	3	11
7	—	8	6	15	10	3⅝	3½	2⅝	1	2	3	11
8	—	7	6	15	14	3⅝	3½	2	3	2	3	10
9	—	7	6	16	14	3¼	3½	2	1	1⅞	2⅞	9
10	22	6	5½	16	15	3⅛	3	2	1	1⅝	2⅝	8
11	20	5	5½	14	16	3⅛	3½	2	2	1⅝	2⅝	11
12	17	4	5½	14	18	3⅛	3	2	1	1⅝	2⅝	20
13	17	4	5⅛	14	20	3⅛	3	1⅝	1	1⅝	4	24
14	17	4	5½	13	18	3⅛	2⅞	1⅝	1	1⅝	4⅛	22
15	16	4	6	13	16	2⅞	2⅝	1⅝	1	1⅝	4⅛	19
16	16	4	7	12	12	2⅞	2½	1⅝	1	2	4½	16
17	17	4	6	12	10	3	2⅛	1⅝	1	3	4½	16
18	22	4	6	13	8	3	2⅛	1½	1	3	4	14
19	19	4	5½	12	8	3½	2½	1⅝	1⅛	3	4	13
20	18	4	5½	15	7	4	2⅛	1⅝	1⅛	2½	4	12
21	15	4½	7	13	6	6	2½	1½	1¼	2½	3⅞	11
22	12	4½	8	11	6	6	2⅛	1⅝	1⅛	2⅛	3⅝	11
23	10	4	21	11	5⅝	5	2	1½	1⅛	2⅛	4	17
24	9	4	31	10	5½	5	1⅞	1½	1⅛	2½	5	20
25	9	4	32	10	5⅝	5	2⅝	1⅝	1⅛	2⅞	8	18
26	8	4	30	10	5⅝	6	2⅝	1⅝	1⅛	2⅝	11	17
27	8	4	28	9	6	5½	2⅝	1⅝	1⅛	3	10	15
28	7	4½	30	8	6	5½	2⅝	1½	1⅛	3½	9	10
29	8	—	34	10	6	5	2⅝	1½	1⅝	3½	8	9
30	8	—	33	12	5½	6	2⅝	1⅛	2⅝	3	8	8
31	10	—	30	—	5½	—	2	1⅛	—	3	—	8

INDEX.

INUNDATIONS OF THE DELTA.

PART I.

	PAGE
Introduction,	17
Formation of the Delta of the Mississippi,	21
Width of the Mississippi,	27
Depth of the Mississippi,	31
Section of the Mississippi,	34
Velocity of the Mississippi,	35
Volume of Water discharged by the Mississippi,	41, 125
Laws of Drainage,	46
Crevasses,	53
Changes and Irregularities of the Mississippi,	59

PART II.

CAUSES OF INCREASING OVERFLOWS.

Prolongation of the Delta,	64
Cut-offs,	77
Effects of Cultivation,	83
Areas drained by the Mississippi and its Tributaries,	88
Extension of the Levées and its Effects,	92
Section across the Delta,	110

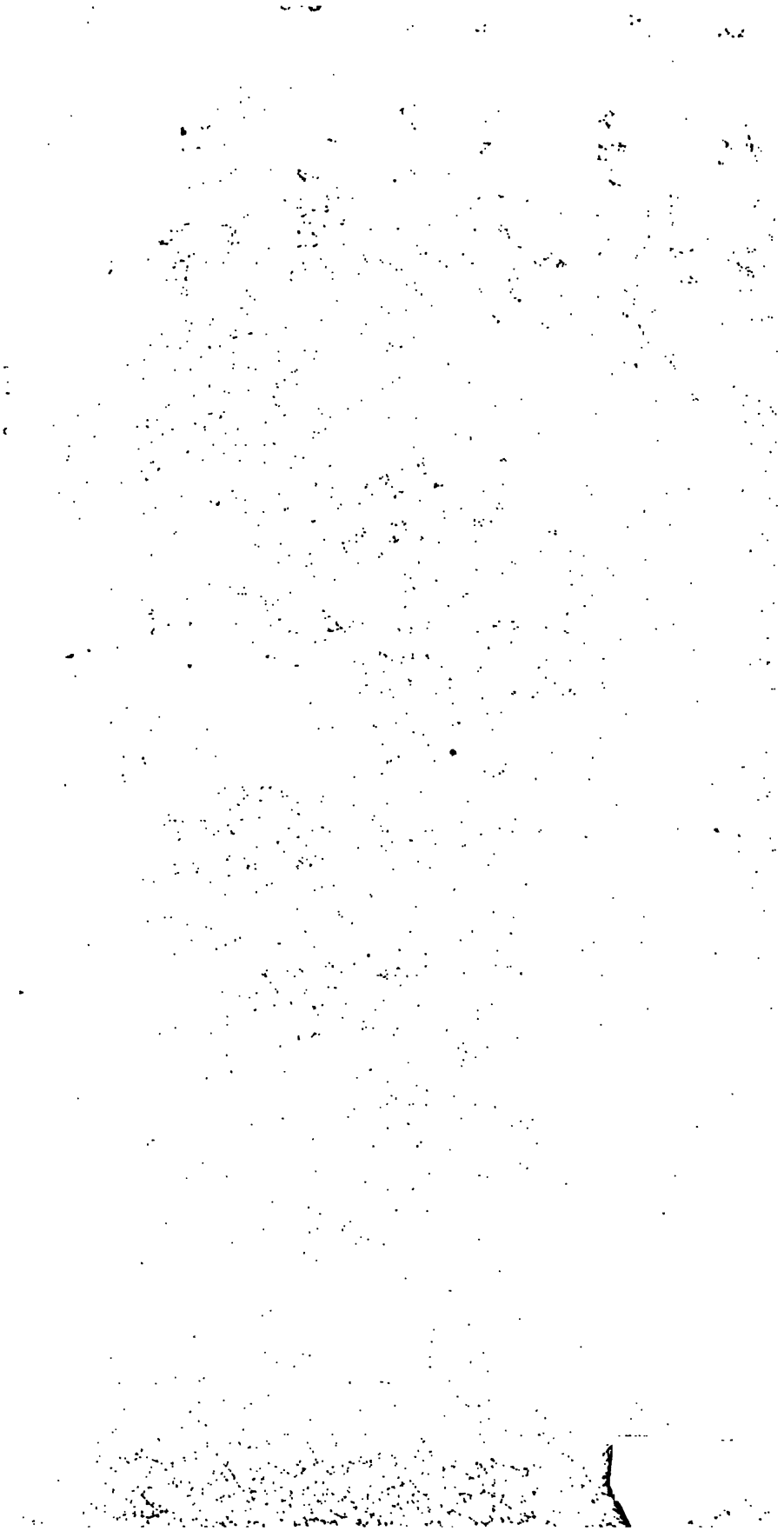
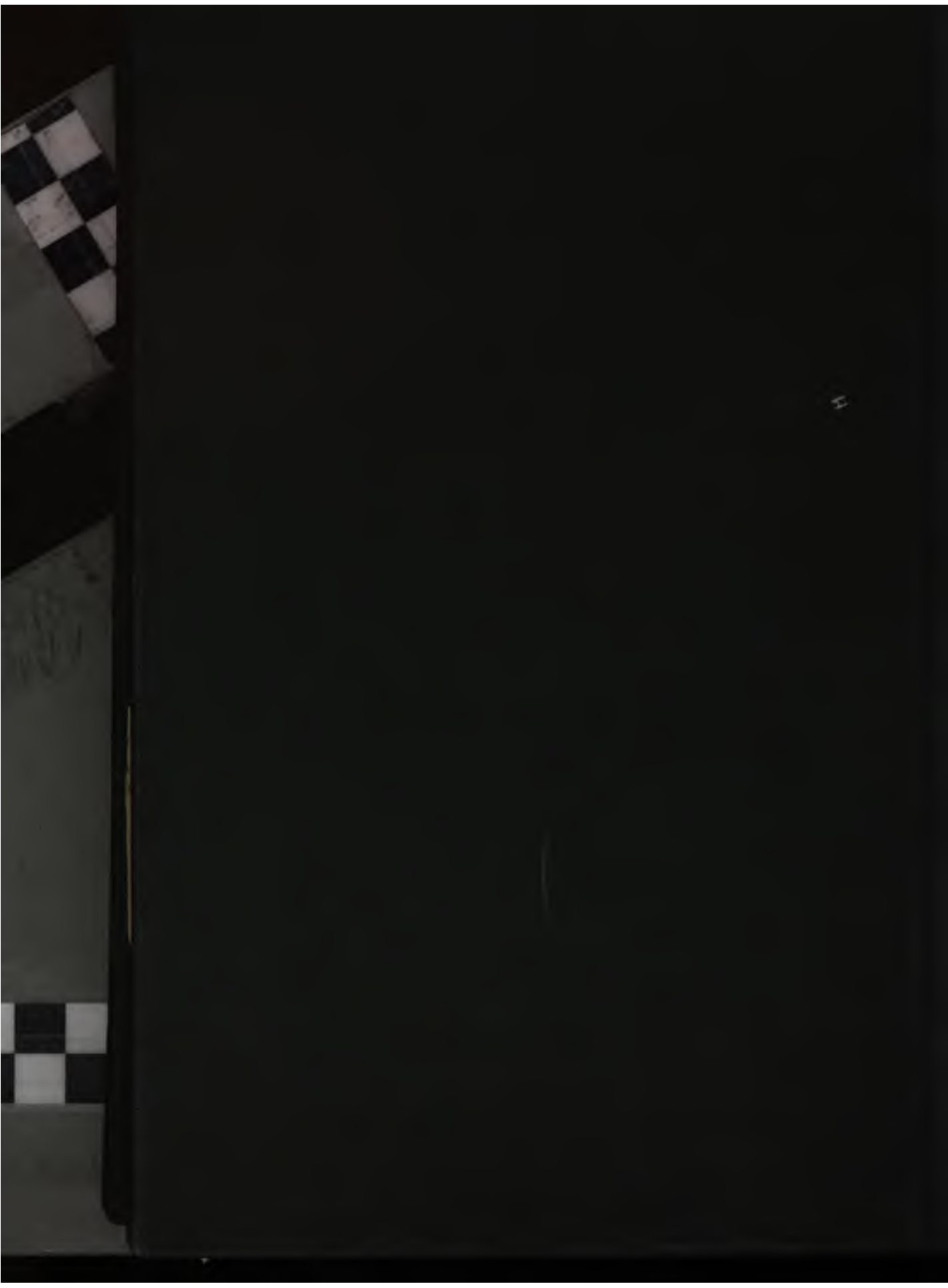
PART III.

MEANS OF PREVENTING INUNDATIONS.

PAGE

Outlets considered, ... 135
Outlets below New Orleans, ... 146
Enlargement of the Plaquemine, ... 151
Enlargement of the Atchafalaya, ... 157
Origin of the Atchafalaya, ... 159
Discharge of the Atchafalaya, ... 163–165
Outlet into Lake Pontchartrain, ... 170
Outlet at the Mouth of the Arkansas, ... 180
Bayou Manchac, ... 181
The La Fourche, ... 182
Prevention of Cut-offs, ... 186
Protection by Levées, ... 196
Reservoirs, ... 205
Position of Louisiana, ... 223

IMPROVEMENT OF THE OHIO.

Physical Geography of the Mississippi Valley, ... 227
Of the Ohio River, ... 231
Fall of the Alleghany, Ohio, and Mississippi, ... 234
Elevations of the Ohio River above Tide, ... 236
Profile of the Ohio and its Tributaries, ... 240
Cumberland, Tennessee, and Wabash Rivers, ... 244
Drainage of the Ohio, ... 253
Volume of Water discharged by the Ohio in various stages, 258–261
Discharge of the Ohio in 1848, ... 266
Discharge for Six Years, from 1843 to 1848, ... 293
Floods of the Ohio, ... 295

PAGE
Means of preventing Injurious Floods, ... 298
Velocity of the Flood-wave, ... 300
Improvement of the Navigation of the Ohio, ... 306
Water-Power, ... 317
Rivers to which Improvement by Reservoirs is applicable, . . 319